

2011

Chemical Safety Training: Lessons Learned from a Model for Evaluating Effectiveness

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**Chemical safety training:
lessons learned from a model for evaluating effectiveness**

by

James Hale Withers

A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Industrial Education & Technology

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Ames, Iowa

2011

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ABSTRACT

A research study was undertaken that examined issues related to evaluating the effectiveness of safety training. Specific research areas were identified after a thorough review of the literature. Research questions were identified and evaluated with the context of evaluating a chemical safety training course offered at Iowa State University in both classroom and computer-based formats. The first major focus of the study was on the development and testing of a “model” that could be used to develop and then evaluate the effectiveness of the training. The second major focus area was related to examining learning and retention of course material; characteristics of the learner that may influence learning were also evaluated. The third focus area examined nuances associated with the assessment techniques used to measure learning. Results of the first focus area showed that the model was a very useful mechanism by which data could be collected, analyzed and then used by the safety professional to improve the effectiveness of safety training. Results of the second focus area showed that there were no significant differences in learning and retention between study participants taking the training on computer versus in the classroom; learner characteristics did not impact the observed amount of learning in either group. Results of the third focus area showed the importance of evaluating and considering characteristics associated with the assessment technique such as question and exam difficulty relative to interpreting the measured amount of learning. The study concludes with a summary of lessons learned information related to each of the three focus areas and suggests that more extensive research be conducted and that the day-to-day safety practitioner can play a key role in advancing the state of knowledge of evaluating training effectiveness.

CHAPTER 1: GENERAL INTRODUCTION

Global competition and rapidly changing technology have made employee training and retraining critical to an organization's productivity and long-term growth (Williams & Zahed, 1996). Providing employees with timely and meaningful training is essential in order for organizations to provide the necessary skills that will ensure performance. A 1991 study of corporate training policies and their implementation in five countries showed training has become a more important element of strategic planning and the highest levels of management are making training decisions (Talley, 2000; Dupont & Reis, 1991). Paradise (2007) reported that the total cost of employee training in the United States exceeds \$126 billion annually. Clearly, the financial stakes involved with implementing a training program are significant and demand that this be a key focus area for every organization.

Nowhere is the importance of providing high quality training more evident than in the area of employee safety training. The necessity of knowing how best to conduct safety training was vividly brought to the general public's attention after the terrorist attacks of September 11, 2001, relative to the actions of emergency responders and their lack of training (Rudman, 2003). While health and safety training is globally recognized as a means of reducing costs associated with workplace injuries and illnesses (Overman, 2005), a study conducted by the National Institute of Occupational Safety and Health (NIOSH) and published in 2010 identified a surprisingly low number of high quality published studies looking at the effectiveness of safety training (Robson, 2010).

In the work environment, employee safety training is a key part of any organization's overall occupational safety and health program and mandated by a number of federal agencies, most notably the Occupational Safety and Health Administration (OSHA). OSHA's belief is that training is an essential part of every employer's safety and health program for protecting workers from injuries and illnesses (OSHA, 1998). For example, training of employees on the hazards of chemicals leads to the establishment of effective control methodologies, an essential component of any accident or exposure reduction strategy. Even though the Occupational Safety and Health Act (OSHA, 1970) does not specifically address the responsibility of employers to provide health and safety information and instruction to employees, Section 5(a)(2) requires that each employer "shall comply with occupational safety and health standards promulgated under this Act." (OSHA,1998). Currently, the term "employee training" appears in more than 270 OSHA standards (Janicak, 1999). Every work environment has a unique set of potential hazards. Successful hazard mitigation strategies must necessarily include effective training.

Developing a safety training program that is effective is particularly challenging in an academic environment. High turnover rates are characteristic of this type of work environment where ironically "success" is partially measured by the numbers of people entering and leaving the institution (Talley, 2000). At Iowa State University (ISU), training is a key part of an overall organizational safety program. Specifically, the philosophy of safety training at ISU is stated as follows (Environmental, Health and Safety, 2005):

Training plays an important role in EH&S's efforts to create a safe environment for the university community, while maintaining regulatory compliance.

Meeting safety and training requirements is a cooperative effort:

- Employees are responsible for performing their work in a safe and responsible manner. Knowledge of appropriate safe work procedures and safety rules is essential.
- Supervisors are responsible for providing and documenting the initial and continuing safety training necessary to allow employees to perform their work safely. This must include frequent work observations by the supervisor and prompt correction of unsafe work habits.
- Departments at Iowa State are responsible for meeting regulatory requirements, keeping work areas hazard-free, and ensuring that employees have completed all safety training requirements.

Based on the decentralized structure of the academic environment, flexibility in how safety training is offered is paramount. Essentially, it could be argued that flexibility is an integral part of evaluating the effectiveness of a safety training program and/or a particular course.

Thankfully, several organizations have developed guidance information to assist the safety professional with accomplishing this task. The OSHA booklet entitled "Training Requirements in OSHA Standards and Training Guidelines" (OSHA, 1998) provides a model for the safety professional to follow when devising a safety training program and includes the following steps:

- 1) Determining if Training is Needed
- 2) Identifying Training Needs
- 3) Identifying Goals and Objectives
- 4) Developing Learning Activities
- 5) Conducting the Training

- 6) Evaluating Program Effectiveness
- 7) Improving the Program

The American National Standard Institute (ANSI), a consensus organization, partnered with the American Society of Safety Engineers (ASSE) and published a guidance document entitled *Criteria for Accepted Practices in Safety, Health, and Environmental Training* (ANSI/ASSE, 2009) that identifies the following essential components of an effective training program:

- 1) Training Program Administration and Management
- 2) Training Development
- 3) Training Delivery
- 4) Training Evaluation
- 5) Documentation and Record Keeping

Finally, the National Institute of Occupational Safety and Health (NIOSH) (Cohen & Colligan, 1998), the research component of the OSH Act, lists the following as essential elements:

- 1) Needs Assessment
- 2) Establishing Training Objectives
- 3) Specifying Training Content and Media
- 4) Accounting for Individual Differences
- 5) Specifying Learning Conditions
- 6) Evaluating Training
- 7) Revising the Training

A review of the OSHA, ANSI and NIOSH lists of essential elements shows many commonalities that can be synthesized into a proposed model by which training can be developed and evaluated (see Figure 1). The safety professional must give careful consideration to each individual step in the hierarchy in order to achieve the most effective training for each safety course. In fact, it could be argued that this process must

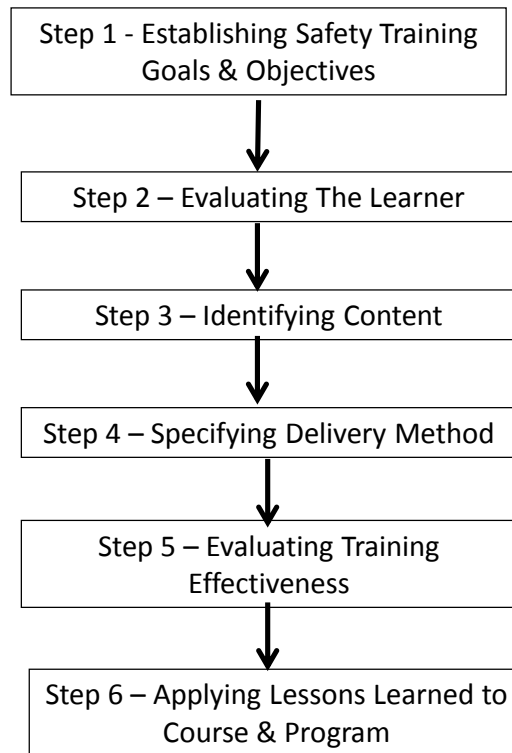


Figure 1 – Proposed Model for Development & Evaluation of Safety Training

be applied to every safety course before an organization's entire safety training program can be judged to be functioning effectively.

Step 1 - Establishing Safety Training Goals & Objectives

The first step in devising an effective safety training course is to define the desired goals and objectives. What should the participant be able to demonstrate upon completion of the training? Is demonstration of knowledge of a particular organizational procedure via written exam the desired outcome? Perhaps demonstration of the proper use of a fire extinguisher to put out a simulated fire is the desired goal of a successful

training course. In a recent literature review funded by NIOSH, four categories of learning outcomes were identified: knowledge (typically shown via a written exam covering a particular policy, procedure or hazard), attitudes & beliefs (including perception of risk), behaviors (meaning worker actions) and health (meaning resulting injuries and illnesses) (Robson et al., 2010).

Table 1 shows a breakdown of the current courses offered at Iowa State University. It should be noted that under “Assessment Technique”, the majority of courses have successful completion of a written exam that tests knowledge as the identified goal or objective. It should be obvious that the success of any safety training course or program cannot be evaluated without first defining goals and objectives.

Step 2 - Evaluating The Learner

As challenging and important as establishing goals and objectives are, the needs of the individual learner must also be considered. Specifically, the safety professional must consider the potential impact of differences in characteristics amongst students taking the same safety training course. In some cases, fundamental characteristics of the learner will drive key decisions on how best to deliver safety training. For example, Kirsch et al. (2007) recently reported that literacy amongst the U.S. workforce is eroding and will continue to do so until 2030. In certain work environments where literacy is a potential concern, it might be concluded that a verbal presentation of safety information

COURSE TITLE	DELIVERY METHOD	ASSESSMENT TECHNIQUE	ENGAGEMENT LEVEL
Suspicious Package Recognition	Classroom – Lecture	Practical Exam	Medium
USDA Regulations: Field Tests Involving Plants Engineered for Pharmaceutical or Industrial Compounds	Classroom – Lecture	Written Exam	Low
Autoclave Safety	Computer – Narrated/Read Material	Written Exam	Low
Biohazardous Materials – An Introduction	Computer – Narration/Read Material	Written Exam	Low
Biological Cabinet: Working Safely	Computer – Narration/Read Material	Written Exam	Low
Biosafety in Microbiological and Biomedical Laboratories	Computer – Narration/Read Material	Written Exam	Low
Bloodborne Pathogens and Sharps Safety Training for Custodial Personnel	Computer – Narration/Read Material	Written Exam	Low
Bloodborne Pathogens and Sharps Training – Facilities-Utilities Personnel	Computer – Narration/Read Material	Written Exam	Low
Bloodborne Pathogens and Sharps Safety Training- Health Care Workers and First Responders	Computer – Narration/Read Material	Written Exam	Low
Bloodborne Pathogens and Sharps Safety Training - Lab Personnel	Computer – Narration/Read Material	Written Exam	Low
10-Hour Incinerator Operator	Classroom – Lecture	Written Exam	Low
OSHA 8-hour HAZWOPER Refresher: Online and Classroom	Computer – Narration/Read Material Classroom – Lecture & demonstration	Written Exam Practical Exam	Low Medium
Regulated Materials Facility (RMF) Training	Classroom – Lecture & demonstration	No exam	Medium
Spill Control and Stormwater Pollution Prevention	Classroom – Lecture	No exam	Low
Fire Safety & Extinguisher Training	Computer – Narration/Read Material	Written exam	Low
Hands-on Extinguisher Training	Classroom – Demonstration	Practical	Medium
Hazardous Materials Shipping Awareness	Computer – Narration/Read Material	Written Exam	Low
ISU Surplus Recovery	Computer – Narration/Read Material	Written Exam	Low
Accident Investigation for Supervisors	Classroom – Lecture & demonstration	Written exam & practical	Medium
Agriculture Worker Protection Safety	Classroom – Lecture & demonstration	Written exam & practical	Medium
Asbestos Awareness	Classroom – Lecture	Written exam (pre post-test)	Low
Asbestos Refresher	Classroom – Lecture	Written exam (pre/post-test)	Low
CPR & AED Certification	Classroom – Lecture & demonstration	Practical exam	Medium
Confined Spaces Entrant	Classroom – Lecture	Written exam	Low
Electrical Safety and Lockout/Tagout	Classroom – Lecture	Written exam	Low
Fall Protection	Classroom – Lecture	No exam	Low
Forktruck Safety	Classroom – Lecture & demonstration	Written & practical exam	Medium
Hot Work Permit Guidelines	Classroom – Lecture	No exam	Low
Introduction to Laboratory Safety	Classroom – Lecture	No exam	Low
Laboratory Safety: Fundamental Concepts	Computer – Narration/Read Material	Written exam	Low
Lab Safety: Chemical Storage and Fume Hoods	Classroom – Lecture & demonstration	Practical	Medium
Lab Safety: Compressed Gas Cylinders	Classroom – Lecture-Demonstration	Written exam	Low
Lab Safety: Spill Procedures	Classroom – Lecture-Demonstration	Practical exam	Medium
Laser Safety Awareness	Computer – Narration/Read Material	Written exam	Low
Lead Awareness	Classroom – Lecture	Written exam	Low
Office Ergonomics	Classroom – Lecture & demonstration	No exam	Low
Personal Protective Equipment	Classroom – Lecture-Demonstration	Written exam	Low
Respirator Initial Certification	Classroom – Lecture & demonstration	Written & practical exam	Medium

Table 1. Summary of Safety Training Courses at Iowa State University.

COURSE TITLE	DELIVERY METHOD	ASSESSMENT TECHNIQUE	ENGAGEMENT LEVEL
Respirator Recertification	Classroom – Lecture & demonstration	Written & practical exam	Medium
Safeguarding Mechanical Hazards	Classroom – Lecture	Practical exam	Low
Scaffold Safety	Classroom – Lecture & demonstration	Written & practical exam	Medium
Scissors and Boom Lift Safety	Classroom – Lecture & demonstration	Written & practical exam	Medium
Sprains and Strain Prevention	Classroom – Lecture	No exam	Low
Tractor Safety	Computer – Narration/Read Material	Written exam	Low
Management of Unwanted Materials - Ancillary Personnel	Computer – Narration/Read Material	Written exam	Low
Management of Unwanted Materials - Laboratory Personnel	Computer – Narration/Read Material	Written exam	Low
Management of Unwanted Materials - Maintenance & Custodial Personnel	Computer – Narration/Read Material	Written exam	Low
Nanotechnology Safety	Computer – Narration/Read Material	Written exam	Low
Radiation Safety for Ancillary Personnel	Computer – Narration/Read Material	Written exam	Low
Radiation Safety for Material Users Refresher	Computer – Narration/Read Material	Written exam	Low
Radiation Safety for Non-Radiation Workers	Computer – Narration/Read Material	Written exam	Low
Sealed Source Radiation	Computer – Narration/Read Material	Written exam	Low
Tax-Free Ethanol	Computer – Narration/Read Material	Written exam	Low
Worker Right-To-Know	Computer – Narration/Read Material	Written exam	Low
X-Ray Safety Fundamentals	Computer – Narration/Read Material	Written exam	Low
Moisture Gauge Training	Classroom – Lecture & demonstration	No exam	Medium
Radiation Safety for Material Users	Computer – Narration/Read Material	Written exam	Low
	Classroom – Lecture & demonstration	Practical exam	Medium

Table 1. Summary of Safety Training Courses at Iowa State University (continued).

is more effective than a written presentation. College campuses are a unique occupational setting with a diverse population both educationally and ethnically. Clearly, this presents a significant challenge to the safety professional when devising a training course that must meet the needs of all learners. Locally, the demographics of safety training course attendees at ISU have included both males and females, different levels of education (high school diploma to Ph.D.), an age range of 18 to over 70, a variety of ethnicities including Asian, Eastern European, Hispanic, African-American and Caucasian, and participants for whom English is a second language. Because the majority of training participants are students, the current minority student demographic data for ISU shown in Figure 2 (A. Gonsamer-Topf, personal communication, November

	Undergraduate	Veterinary Medicine	Graduate	Total
American Indian or Alaskan Native	51	1	13	65
Black	572	1	148	721
Asian	649	1	90	743
Native Hawaiian or Other Pacific Islander	13	0	0	13
Hispanic/Latino of any race	729	10	93	832
Two or more races	214	2	25	241
Total Minority	2,228	18	369	2,615
Total Enrollment	23,104	587	4,991	28,682
% Minority	9.64	3.07	7.39	9.12

Figure 2 – 2010 Minority Student Demographic Data – Iowa State University

17, 2010) provides an accurate, overall ethnic profile of the population of training participants for this study.

When considering again the six step process for developing safety training, it could be argued that the specific issue of differences in characteristics of the learner could potentially affect every step. In fact, there are many examples in the literature where employee safety training was evaluated relative to a variety of characteristics of the learners. On age diversity, Wallen and Mulloy (2006) evaluated different types of computer-based respirator training and found that younger workers did better than older workers in general and that versions that contained both pictures and audio narration

resulted in the greatest amount of learning. Their conclusion was that computer-based safety training should be designed and selected based on the ability to train older as well as younger workers. Bosco and Wagner (1988) evaluated a group of 209 auto workers who received instruction on the safe use of solvents via either an interactive/video format or classroom format and analyzed learning relative to demographic factors such as age, sex, years of experience and years of education and found that only education had a weak effect on post-test scores. Fivizzani (2005) points out the importance of flexibility in how training is offered (to reflect different learning styles) and diversity issues such as employees who speak English as a second language. On the issue of educational levels, Williams & Zahed (1986) noted that it had no impact on subjects' learning or retention regardless of whether they took chemical hazard communication training in the classroom or on the computer. Gutierrez and Rogoff (2003) point out the complexity of using ethnic differences as a method of summarizing a group's learning style. They argue that the educational system in the United States needs to "get beyond a widespread assumption that characteristics of culture groups are located within individuals as "carriers" of culture" and that this has created many problems when applied in schools (Gutierrez & Rogoff, 2003, pp. 19-25). Language proficiency of the learners has also been studied by several researchers (Heil & Aleamoni, 1974; Riggs, 1982; Abadzi, 1984; Burgess and Greis, 1984) who found that the correlation between academic success and language proficiency is low in magnitude but nevertheless positive and significant. Does the number of years of experience performing an activity (or working with chemicals, in this case) impact the efficacy of safety training? Goldrick (1989) reported that nurses who took infection control training on a computer demonstrated higher learning (based

on post-test scores) than those who took the training in the classroom and the results were independent of educational level and work experience.

Another factor that should be considered when evaluating “characteristics” is the overall satisfaction of the learning experience by the participant. Relative to the emergence of new learning technologies like computer-based instruction, early research on satisfaction with training focused on the overall acceptance of computer-based training. Bowan, Grupe and Simkin (1995) studied a group of beginning level computer users and found that both experimental groups (computer-based training (CBT) & classroom) were equally satisfied with the training. However, meeting the needs of every learner can be extremely challenging for the safety professional given the diverse demographics and preferences of the students (e.g. ethnicity, age, experience) previously discussed. Gronbacher (2005) conducted a marketing survey of safety professionals and found that boredom was the greatest obstacle to effective safety training! With the increase in popularity of video games, younger participants, for example, might have a more difficult time paying attention to a lecture only presentation. Umbrell (2005) reported that some global workforces have as many as five generations of workers, each with differing cultural and education backgrounds, who share the same safety training program! Fivizzani (2005) correctly points out that training should be flexible enough to utilize several teaching/learning styles and perhaps involve options for participants.

Despite the complexities suggested by the previous discussion and references, it clearly behooves the safety professional to give some consideration to the characteristics of learners when devising a training course.

Step 3 - Identifying Content

Most OSHA regulations with training requirements offer specific information on the required content. As an example, OSHA's Occupational Exposures to Chemicals in Laboratories (29 CFR 1910.1450) regulation (also known as the Laboratory Standard) states the following training requirements for laboratory workers under section (f) (OSHA, n.d.):

Employee information and training:

(1): The employer shall provide employees with information and training to ensure that they are apprised of the hazards of chemicals present in their work area.

(2): Such information shall be provided at the time of an employee's initial assignment to a work area where hazardous chemicals are present and prior to assignments involving new exposure situations. The frequency of refresher information and training shall be determined by the employer.

(3): Information. Employees shall be informed of:

(i) The contents of this standard and its appendices which shall be made available to employees;

(ii) The location and availability of the employer's Chemical Hygiene Plan;

(iii) The permissible exposure limits for OSHA regulated substances or recommended exposure limits for other hazardous chemicals where there is no applicable OSHA standard;

(iv) Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory; and

(v) The location and availability of known reference material on the hazards, safe handling, storage and disposal of hazardous chemicals found in the laboratory including, but not limited to, Material Safety Data Sheets received from the chemical supplier.

(4): Training.

(i) Employee training shall include:

- (A) Methods and observations that may be used to detect the presence or release of a hazardous chemical (such as monitoring conducted by the employer, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.);
 - (B) The physical and health hazards of chemicals in the work area; and
 - (C) The measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used.
- (ii) The employee shall be trained on the applicable details of the employer's written Chemical Hygiene Plan.

In this example, parts of the required content dictated by the regulation are very prescriptive (e.g. 3 (iii) – Location and availability of the Chemical Hygiene Plan). Other parts, however, are open for interpretation in terms of required content (e.g. (C) The measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used). Depending on the organization and the size of the safety office staff, the process of establishing identifying essential course content may be done unilaterally by the trainer (generally a subject matter expert) or as a part of collaborative effort by several safety professionals with relevant expertise.

Another example is given in OSHA's lock out/tag out regulation (OSHA, n.d.) in 1910.147(c)(7)(i) where it states:

The employer shall provide training to ensure that the purpose and function of the energy control program are understood by employees and that the knowledge and skills required for the safe application, usage, and removal of the energy controls are acquired by employees.

Again, it can be argued that required content for a lock out/tag out safety training course is up for debate. For example, what “knowledge and skills” are required of the employee in order to successfully mitigate the potential hazard of say electrical energy and, therefore, should be included in the safety training?

Step 4 - Delivery Method

In the previous examples of OSHA-mandated training, the content of the training was specified but no particular methodology for instruction or criteria for demonstration of knowledge was given. In fact, OSHA leaves these details to the employer (OSHA, 1998):

In addition to organizing the content, employers must also develop the structure and format of the training. The content developed for the program, the nature of the workplace or other training site, and the resources available for training will help employers determine for themselves the frequency of training activities, the length of the sessions, the instructional techniques, and the individual(s) best qualified to present the information.

Safety professionals that have been practicing for more than 10 years can most likely relate to methodologies used for safety training in the not too distant past. A commercially-available, topic-specific video would be purchased from a vendor, shown to the audience and the training intervention would then be deemed a “success”. In this context, an evaluation of the effectiveness of the training would be superseded by the need to simply “get the training done”. At this step, the safety professional is wise to consider Dale’s “Cone of Learning” shown in Figure 3 (adapted from Dale, 1969).

CONE OF LEARNING		
<i>After 2 weeks we tend to remember</i>		<i>Nature of Involvement</i>
90% of what we say and do	Doing the Real Thing	Active
	Simulating the Real Experience	
	Doing a Dramatic Presentation	
70% of what we say	Giving a Talk	
	Participating in a Discussion	Passive
50% of what we hear and see	Seeing it Done on Location	
	Watching a Demonstration	
	Looking at an Exhibit Watching	
	Watching a Movie	
30% of what we see	Looking at Pictures	
20% of what we hear	Hearing Words	
10% of what we read	Reading	

Figure 3 – Cone of Learning (adapted from Dale, 1969)

Briefly, this learning model states that maximum learning and subsequent retention of information occurs by a more “hands on” methodology. While Dale’s theory has had its critics (Coffey and Gibbs, 2002; Molenda, 2003; Thalheimer, 2006), other researchers have found the rankings and approximate percentages to hold true (Cross and Angelo, 1988; Bligh, 1998; Lord, 2007).

A more contemporary discussion of Dale’s theory was posited by Burke (2006) who classifies the levels of training engagement as low, moderate and high. Lectures are an example of low engagement or “passive” training that are “commonly used to present

health and safety-related information” (Burke, 2006, p. 315). Moderately engaging techniques include demonstration of knowledge via a feedback mechanism that allows the student to correct their own mistakes through feedback from the instructor or, in the case of a computer-based training method, via feedback from the course. Highly engaging training involves a modification of behavior (Dale uses the term “active” to describe the “nature of involvement”). Which method is best for a given safety course is determined by a variety of factors. Learning preferences of the students, teaching preferences of the trainers, organizational aims, and resources all must be given consideration (Coppola and Myre, 2002). Included in “organizational aims” would be the desired outcome of the training (e.g. demonstration of knowledge, etc.).

However, while considering the merits of highly engaging safety training, an obvious limitation comes to light. There is a direct relationship between the more engaging or active methods of training and both the amount of time invested in developing and then conducting the training. Relative to the development of computer-based instruction, Rubenstein (1999) reported that developmental costs for a customized, highly interactive computer-based course may reach \$200,000-300,000 excluding the cost of software upgrades. At this juncture, organizational leaders and safety managers have to agree on the appropriate amount of resources to devote to the training program. In an ideal world, all safety training would be highly participatory. However, this is not realistic and as Burke points out, most safety training conducted today tends to be low-engaging or passive in its methodology. In fact, a NIOSH review of published studies looking at safety training effectiveness identified traditional methods of lectures and use of printed

materials (i.e. low engagement) were most common (Robson et al., 2010). Referring to Table 1 again, an analysis of current health and safety training offered at ISU in terms of level of engagement based on Burke's definitions. As can be seen, the majority of courses currently offered would be classified as low-engagement.

After considering the implications of the level of engagement of training, it is appropriate to reflect on the impact of the increased use of computers for safety training. Advances in computer technology have allowed organizations including universities increased flexibility in how and when training courses are offered. Buren & Erskine (2002) reported that 8.8 % of companies used learning technologies to deliver training in 2002. Undoubtedly, that percentage is higher today. Part of the appeal of computer-based technologies for the safety professional is the possibility of offering safety training "on demand". Employers can get new employees trained and on the job quickly with required safety training that is readily available. A study conducted by the International Data Corporation (Overheul, 2002) projected that 80% of safety training would be conducted via a computer by 2003! Clearly, the use of computer-based safety training has caught on as evidenced by the widespread availability of off-the shelf computer-based training courses from vendors such as Summit Training Source whose website touts programs that "have been the choice of thousands of U.S. based and international organizations since 1981" and offer "more than 600 tested and proven training programs in a variety of formats and languages" (Summit Training Source, 2011) and reported annual sales of \$5M in 2009 (Hoovers, 2011). As far back as 1999, Lawson encouraged safety professionals to "accept the challenge and begin to examine these [computer-

based] technologies and their application in safety.” (Lawson, p.32). A survey of safety professionals done in 2001 showed more than 70% expected online training would be among their main delivery vehicles for safety training within the next five years (Overheul, 2002). Table 1 also shows a breakdown of ISU health and safety courses that are offered in the classroom and on computer. This tremendous growth in the use of technology to deliver training has led to extensive research on the effectiveness of classroom versus computer-based training.

Classroom Versus Computer-Based Instruction

Traditional lecture (classroom) instruction has many advantages over other methods including opportunity for discussion and interaction, dissemination of large amounts of information to a large number of people in a short period of time, greater control over whether students finish a course, ease of course development, ability of instructors to motivate students to learn and perform, and wide acceptance as an approach to teaching (Yoder & Heneman, 1977; Hasselbring, 1986; Ganger, 1990; Harrap, 1990; Della-Guistina & Deay, 1991). Potential weaknesses of traditional classroom instruction include passive listening, limited trainee involvement, limited effectiveness of skill acquisition, limited skill and effectiveness of the trainer, diminished control over relevance of material presented, limited or fixed time for presentation and limited individual attention or instruction (Gery, 1987; Griffin, 1989; North, 1989; Myers, 1990).

Advantages of computer-based instruction have also been well documented and include increased accessibility, individualized self-paced instruction, automated

recordkeeping, control of the training process, not subject to the skills and availability of an instructor, potential for reduced training time, program interactivity, timely and targeted feedback and reinforcement, individualized instruction, reduced likelihood of error in presentation of content, and consistency in presentation (Goldstein, 1980; Schaab & Byham, 1985; Schwade, 1985; Ladd, 1986; Pipeline & Gas Journal Staff, 1988; Furgang, 1989; Forlenza, 1995). A major disadvantage of computer-based training is the cost and time associated with development (Siemasko, 1986). However, studies have shown that long-term benefits may outweigh costs (Reynolds, 1982; Heck, 1985; Knight, 1988; Perez & Willis, 1989). Other disadvantages discussed in the literature include computer phobia and anxiety (Banks & Havice, 1989) and lack of acceptance by instructors (Stemmer, Nolan, & Culler, 1983).

Step 5 - Evaluating Safety Training Effectiveness

After a safety course is developed and launched, there may be no more active involvement by the safety professional. There are many reasons why this occurs. In addition to the development of effective safety training courses, the safety professional has many other time commitments in terms of implementing a safety program. The costs of not evaluating the effectiveness of safety training, however, can be substantial in terms of lost opportunities to improve training and potentially further reduce injuries and illnesses. In fact, only about 50 percent of companies measure learning outcomes from training, and less than a fourth make any attempt to assess potential programmatic improvements resulting from training (Sugrue & Rivera, 2005).

Several reviews of the literature on the impact of safety training have been conducted and conclude that most training “interventions” result in a positive effect on safety knowledge, adoption of safe work behaviors and practices, and safety and health outcomes (Cohen & Colligan, 1998; Burke & Sarpy, 2003; Cohen & Colligan, 2004). Most safety professionals would not find these results surprising. However, the importance of evaluating the effectiveness of safety training cannot be overstated. Goldstein (1989) reported that industrial companies in the United States invest over \$40 billion annually in training without conducting a formal analysis of its effectiveness. An even more compelling case for the need to evaluate safety training effectiveness is made by NIOSH (Robson, 2010, page 1):

Research on the effectiveness of Occupational Health and Safety (OHS) training is needed to: 1) identify major variables that influence the learning process and 2) optimize the allocation of resources for training interventions. In research on training, it is often difficult to arrive at definitive conclusions about effectiveness. Typically, many workplace characteristics contribute to real-world effects of training. Designing studies that validate the unique contribution of individual factors, such as specific training program features, are often infeasible. Traditional narrative literature reviews of training are often speculative about specific factors that enhance the relative effectiveness of OHS training interventions in reducing occupational injuries, illnesses and deaths.

OSHA also discusses the importance of evaluating training effectiveness (OSHA, 1998):

To make sure that the training program is accomplishing its goals, an evaluation of the training can be valuable. Training should have, as one of its critical components, a method of measuring the effectiveness of the training. A plan for evaluating the training session(s), either written or thought-out by the employer, should be developed when the course objectives and content are developed.

But, how does the safety professional go about evaluating effectiveness? A common technique cited by organizations as their way of evaluating training effectiveness is via course evaluations. Course evaluations typically ask for feedback on content, the instructor and other factors such as course relevance and the training facility. The feedback provided by course evaluations is important and valuable, but the NIOSH quote above suggests 1) evaluating training effectiveness is complicated and that 2) the evaluation must go beyond course evaluations and include an assessment of individual learners (i.e. individual factors) and an assessment of the most appropriate delivery methodology (i.e. training program features). With the previously discussed emergence of computer technology and its usage in delivery of safety training, studies have been conducted that evaluate two topics of interest to the safety professional related to safety training information: learning and retention.

Learning

Differences in demonstrated learning between classroom and computer based instruction has been studied extensively across many disciplines. Hasselbring (1986) conducted an analysis of 20 years of research and reported that students who received computer-based training (CBT) demonstrate equal or better achievement when compared to those that received traditional instruction. Kulik and Kulik (1991) reported the results of a meta-analysis of the literature and concluded that students usually learn more in classes in which they receive computer-based instruction with average exam scores being raised .35 standard deviations, or from the 50th to 64th percentile. Bowan, Grupe and Simkin (1995) administered beginning-level computer courses via both CBT and

classroom modes and compared learning experiences. Their results indicate equivalent learning experiences between the two groups in that there was no statistically significant difference in the results of homework or examination scores. Stephenson (1991) reported that when the amount of learning of a software application was compared between those receiving training via CBT versus classroom, students performed better when they received classroom instruction.

In the safety arena, Lawson (1999) evaluated a group of 46 college students who were receiving OSHA blood borne pathogen training via either CBT or the classroom. Students were administered a 30-question, multiple-choice pre-test and post-test (upon completion of training). The results indicate that CBT students scored higher on a post-test administered immediately after training than instructor-led students (an average of 85.7% for CBT versus 64.7% for instructor-led. In the more specific area of chemical safety, Williams and Zahed (1996) looked at 54 employees of a chemical processing plant who received chemical hazard communication training via CBT or classroom. Their results indicate that there was no difference in learning (as indicated by a post-test) immediately after completion of the training.

Retention

The issues of retention of safety information is of interest as several OSHA regulations mandate annual refresher training including bloodborne pathogens (OSHA, n.d.) and hazardous waste and emergency response operations (OSHA, n.d.).

The amount of retention occurring between classroom and computer-based instruction has also been reported in the literature. Lawson (1999) (cited earlier) also studied retention in the same group of college students. Students were administered a 30-question, multiple-choice pre-test and post-test (upon completion of training). Another 30-question post-test was given three weeks later. Results indicated that both groups experienced a similar amount of decrease in test scores after 3 weeks. Booker, Catlin & Weiss (1991) administered a follow up test and questionnaire one year after initial training to a group of 114 asbestos workers and found that retention was better on specific work practice questions than those dealing with other issues. Their results provided an opportunity to assess the original training but the study was not designed as an evaluation effort. Williams and Zahed (1996) noted that retention of chemical hazard communication information after one month was higher for students taking computer-based training than for classroom instruction (85.30% test scores on CBT versus 78.74% for instructor-led). Interestingly, a NIOSH review of recent literature (1996 to present) identified very few studies of safety training that evaluated long term retention and no studies in the chemical safety arena (Robson, 2010).

Assessment Technique

At this point, the safety professional is faced with another challenge. Most safety professionals are not well versed on principles related to exam question design and testing. Weidner (2000) stated that while safety regulations with training requirements are based on known scientific principles related to hazards, they often lack the underpinnings of the principles of adult learning and assessment. This becomes

increasingly important when considering a common measure of success in safety training: achievement of a minimum passing score (percentage) on a post-course test. In general, a 70% score is widely accepted as an indicator of moderate knowledge, 80% of moderately higher knowledge, and so forth (Angoff, 1984). However, the safety professional must wrestle with issues related to question design and exam difficulty in order to establish a meaningful passing level. If it is accepted that training effectiveness is intimately linked to how well the defined goals and objectives defined in Step 1 are achieved, then assessment techniques and, more specifically, question analysis cannot be ignored.

Step 6 - Applying Lessons Learned to Course & Program Improvement

The final step in the process of developing an effective safety training course and program is applying the lessons learned to making improvements. The safety professional must carefully review the data gathered related to effectiveness and make appropriate changes. For example, the data may show that learners do better on computer-based courses than classroom. This might be ample justification for the safety professional to suggest to management that classroom courses be discontinued or offered at a reduced frequency, thus increasing available time for other safety program endeavors. Data on retention of information may show that the student's knowledge of pertinent safety information wanes significantly in the course of the year. The safety professional may use this as justification to management to institute a mandatory annual refresher requirement. If retention data shows very little loss of knowledge, this may suggest that mandatory annual refresher training is not necessary and perhaps other

annual “checks” of knowledge can be utilized, such as a challenge exam. The cost savings (as measured by time spent in the classroom or on the computer) associated with this type of evaluation may be significant. What information can be gleaned from an examination of learner characteristics? Can it be shown that a certain ethnic group performs better in one or the other type of training format? Do older learners prefer classroom sessions because of unfamiliarity with computers? Are there any nuances associated with the assessment technique that influence training effectiveness? There are a myriad of questions that can be evaluated via a comprehensive assessment of safety training effectiveness. Ultimately, this evaluation leads to better safety training.

Research Methods

The six-step proposed model shown in Figure 1 is amenable to serving as the basis for conducting research. First, how well does the overall model work? What information can be learned by an examination of the usefulness of the model? While all steps in the model are important, Step 5- Evaluating Effectiveness is an absolutely critical part of the process that will allow additional, specific feedback on issues related to training effectiveness. Given the lack of practical, case-study data in the literature, a goal of this research project was to utilize the six-step model as a research instrument that would provide answers to a variety of specific research questions. The focus of the study will be a low-engagement, exam-based chemical safety training course at ISU.

Background

ISU EH&S first began providing safety information on-line in 1999. These first courses were not tests but rather resource materials. From 2005 to present, the number of on-line courses has grown from 4 to 33 (R. Book, personal communication, December 6, 2010). In the chemical safety arena, the “Laboratory Safety: Fundamental Concepts” course has been offered both in classroom and computer-based formats and serves as the backbone of the University’s chemical safety program. The fundamentals course provides basic chemical safety programmatic information to the learner and provides a “roadmap” by which a research group-specific safety program can be developed and implemented. Course topics covered include: regulations, terminology, roles and responsibilities, exposure controls and prevention, recordkeeping, exposure monitoring, Material Safety Data Sheets (MSDS), emergency preparedness, Personal Protective Equipment (PPE) and lab maintenance and inspection. In terms of level of engagement, the Fundamentals course would be considered low-engagement training. To date, effectiveness has been measured by the successful completion of a written exam at the end of the course. Because of the necessity for this course to provide information to the learner in an effective manner, it was chosen as the focus of utilizing the six-step process and then proposing and testing of a model for evaluating effectiveness.

Model Step	Research Component
Step 1 – Establishing Goals and Objectives	Convene expert panel consisting of subject matter experts.
Step 2 – Evaluating the Learner	Administer demographic survey during training
Step 3 – Identifying Content	Utilize expert panel feedback and convene focus group
Step 4 – Specifying Delivery Method	Develop data collection methodologies for both classroom and computer-based formats
Step 5 – Evaluating Effectiveness	Perform basic statistical analyses on accumulated data and interpret results
Step 6 – Applying Lessons Learned to Course and Programmatic Improvements	Apply results to specific course improvements and overall program improvements

Figure 4 – Proposed Research Model

Proposed Research Model

A brief description of each of the six steps and the associated research component is shown in Figure 4.

Step 1 – Establishing Goals and Objectives

The first step in the research model was to define a mechanism by which goals and objectives of the training could be established. On the ISU campus, there are two separate, multi-disciplinary safety offices (ISU, Ames Laboratory) each with a staff of safety professionals that have expertise in chemical safety. Specialists from both staffs

were solicited to participate in an “expert panel” to discuss and agree upon key learning outcomes expected after completion of chemical safety training. Topics discussed included the following: pertinent OSHA requirements, roles and responsibilities of chemical users at ISU, how to obtain a Material Safety Data Sheets (MSDSs), requirements for container labeling, how to select appropriate Personal Protective Equipment (PPE), procedures for handling emergencies, and procedures for handling workplace events such as an accident.

Step 2 – Evaluating the Learner

In order to evaluate the learner, a survey mechanism was defined by which key characteristic data could be collected by participants in the project. A survey was devised after consulting the literature and identifying key learner characteristics (see the Literature Review section) that might have an impact on an evaluation of effectiveness of training. Survey experts on campus were also consulted. The survey was administered to both computer and classroom training participants in the study. Learner characteristics solicited were: age, gender, ethnicity, English proficiency, number of previous chemical safety training courses taken, number of years of experience working with chemicals, overall satisfaction with the training experience, and preferences on delivery method (computer versus classroom).

Step 3 – Identifying Content

Identifying appropriate chemical safety content was another task of the convened expert panel. As has been previously mentioned, the fundamentals course was an

established course that covered a variety of chemical safety programmatic elements.

During the course of establishing goals and objectives, the expert panel also engaged in the task of assessing the adequacy of content. Only the most important topics needed to be included in the training. The job of the expert panel was to come to consensus on topics for inclusion in the training.

Step 4 – Specifying Delivery Method

The laboratory fundamentals course was already being offered in two formats: classroom and computer-based. The classroom session was offered approximately three times per year; the computer-based version was available on-line via EH&S's training center 24 hours per day, 7 days per week. In order to accommodate a data collection mechanism, significant review and modification of the two delivery methods (computer, classroom) was necessary and is discussed in Step 5.

Step 5 – Evaluating Effectiveness

The evaluation of effectiveness is a significant and key element of the overall model. Of any of the six steps in the developmental process shown in Figure 1, this step required the most effort. In order to collect data on both learning and retention, a pre-test/post-test format was utilized that was similar to a study conducted by Williams & Zahed (1996). Figure 5 shows the sequence of steps involved in first developing and then validating the data collection tool. A discussion of each of the four steps is as follows:

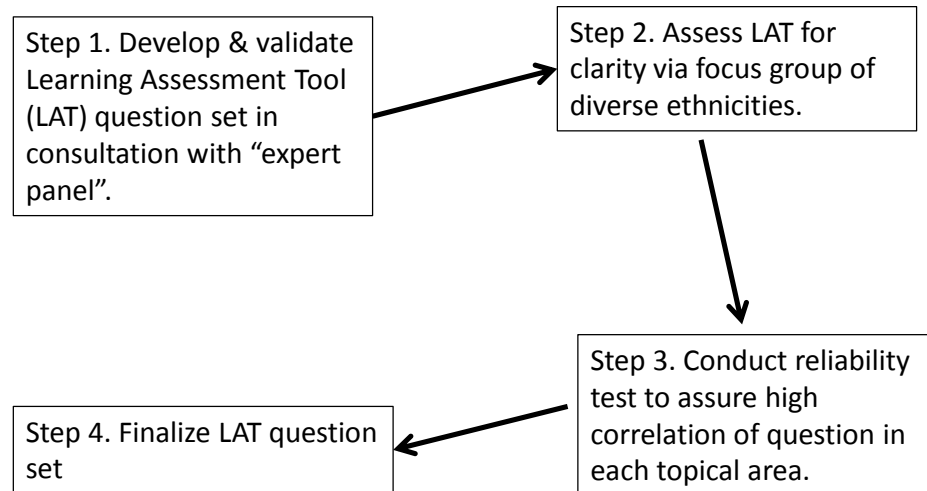


Figure 5 – Development and Validation of Data Collection Tool

Development and Validation of Data Collection Tool. To accommodate the necessary data collection mechanism, a Learning Assessment Tool (LAT) was developed. Developmental steps were as follows:

Step1: Develop LAT in Consultation with Expert Panel

As discussed previously, the expert panel developed a bank of questions that were associated with 16 topical areas of relevance. With 3 questions per topical area, a master question set was devised with a total of 48 questions.

Step 2: Assess LAT for Clarity

To ensure clarity and in recognition of the ethnically diverse nature of the learners, the master question set was first given to a multi-cultural focus group for review. The focus group was asked to read each question and provide feedback on issues of clarity, wording and question structure. The demographics of the focus group included reviewers who had English as a second language and were proficient in one of the following languages: Chinese, English, Russian, or German. The focus group provided feedback on the LAT questions and identified terminology that was confusing or unclear. Focus group comments received were incorporated into the final question sets for the LAT.

Step 3: Conduct Reliability Test

The LAT was next administered to approximately 20 individuals who had completed chemical safety training previously. A correlation analysis was done using a multivariate test (Wilk's' Lambda test statistic) to determine how well each of the 3 questions tested the student on a particular learning outcome. It was anticipated that there would be a high correlation of successful responses to each of the 3 questions for a given topical area assuming knowledge of that learning outcome.

Step 4: Finalize LAT

The results of the correlation analysis were then used to finalize the LAT prior to the beginning of the data collection phase of the study. Questions with lower correlation results were modified via changes in wording and sentence structure. The 48-question

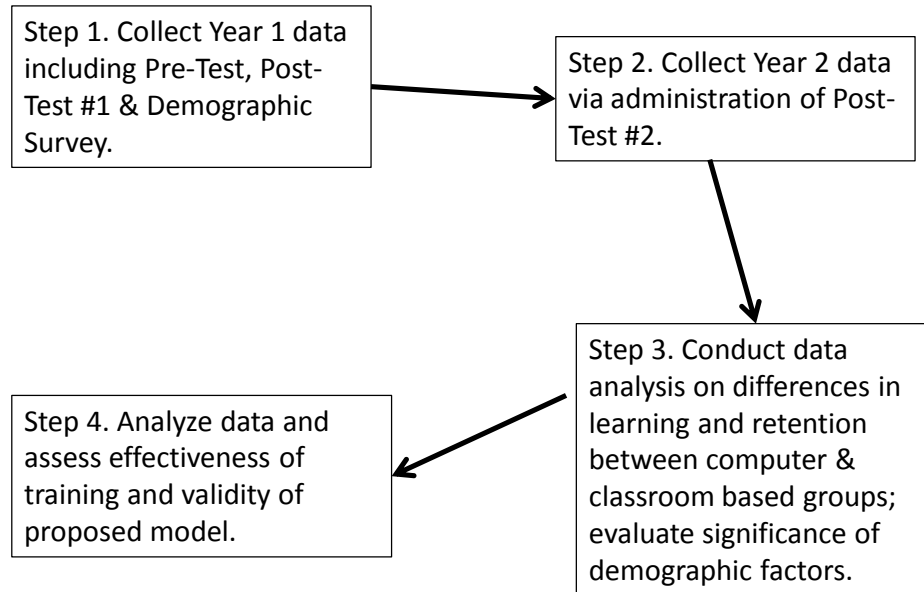


Figure 6 – Data Collection and Analysis

validated LAT was then divided into 3 individual versions of the LAT that are shown in Appendix 1.

Data Collection and Analysis. The second component of the model is the actual collection and analysis of the data. The sequence of steps for data collection has been briefly discussed already and is shown in Figure 6.

Step 1: Collect Year 1 Data

The LAT was administered prior to and after training. In the classroom sessions, the pre-test and post tests were handed out to students. In the computer-based sessions, the pre and post-tests were presented to the student automatically on the computer. In each case, the version (1, 2 or 3) was randomly selected either by the instructor or computer program. Upon completion of the course, a second and different version of the LAT was administered. Participants were introduced to the study via presentation of an informational memo (Appendix 2). Those agreeing to participate were asked to complete the learner characteristic survey (Appendix 3).

Step 2: Collection of Year 2 Data

Study participants were tracked and upon the 1-year anniversary date of completion of training, they were requested to complete and return the third version of the LAT.

Step 3: Conduct Data Analysis

After all tests and surveys were collected for each participant, tests were corrected. The difference between pre and post-course exam scores (as measured by number of questions correct) was interpreted as a measure of the amount of learning resulting from course participation. A second post-test was administered approximately 1 year after completion of the training. The difference between the original post-test and the second was interpreted as a measure of retention of the course material. Summary data was generated using the statistical functions in Excel. Group comparisons were done using t-tests and analysis of variance (ANOVA) models. For example, to determine if learning or

retention was affected by any of the selected learner characteristics, multiple ANOVA models were tested using a particular characteristic (e.g. education level) as a between-subjects factor.

Step 4: Analyze data and assess training effectiveness and model validity

Upon completion of the analysis of the data, the individual research objectives (identified in the next section) will be addressed including the identified specific research questions. The implications of the data will be addressed in terms of the effectiveness of the training and the validity of the overall model.

Research Objectives

Several major research objectives were identified and evaluated using a variety of analytical techniques. Results for each major objective were summarized in separate articles that will be submitted for publication to relevant journals. A summary of each research objective is as follows:

Research Objective #1

A first objective of the study was to evaluate and share lessons learned from utilization of the proposed six-step model for developing and evaluating safety training. Given the lack of practical, case study presentations of utilization of this process, results of this study will be beneficial to other safety professionals and are contained in Chapter 2.

Research Objective #2

Steps 2 (Evaluating Learner), 4 (Specifying Delivery Method) and 5 (Evaluating Effectiveness) all were intimately related to the overall study design. In order to evaluate the issue of learning, a learner characteristic survey was devised that would collect key information about the training participant. Since demonstration of knowledge was the identified outcome, key issues related to learning and retention were explored relative to delivery method (computer versus classroom). An associated research question was defined as follows:

Evaluate levels of learning and retention between trainees receiving chemical safety instruction via computer-based training versus classroom instruction and any potential implications for characteristics of participants related to amount of learning.

Research Objective #3

Another key factor related to Step 4 (Delivery Method) and Step 5 (Evaluating Effectiveness) of the model was an evaluation of the assessment technique used. An exam-based structure for demonstrating successful completion of safety training demands an evaluation of the assessment technique used. As stated in the Research Methods section, a pre and post-test format was used for data collection. Given this methodology, an associated research question was defined as follows:

Evaluate the assessment technique used and potential roles played by question/exam difficulty and order of administration.

Institutional Review Board Approval

This project has been approved by the ISU Institutional Review Board. See Appendix D for approval documentation.

Definition of Terms

ANSI = American National Standards Institute

CBT = Computer-Based Training

EH&S = Environmental Health & Safety

EPA = Environmental Protection Agency

ISU = Iowa State University

LAT = Learning Assessment Tool

OSHA = Occupational Safety and Health Administration

Thesis Organization

The remaining chapters of this dissertation were discussed previously and were formatted as manuscripts that will be submitted to refereed journals for publication. A summary of chapter content and journal are as follows:

Chapter 2 – A case study that describes lessons learned from the development and testing of the evaluation model that will be submitted to the *Journal of Safety Research*.

Chapter 3– A paper discussing the differences in learning and retention between computer-based and classroom learners and the impact of learner characteristics that will be submitted to *Chemical Health & Safety*.

Chapter 4 – A paper discussing the importance of considering the assessment technique when evaluating training effectiveness that will be submitted to the *Chemical Health & Safety*.

Chapter 5 – Summary and Conclusions

CHAPTER 2 - CASE STUDY:
LESSONS LEARNED FROM A PROPOSED MODEL FOR
DEVELOPING AND EVALUATING EFFECTIVE CHEMICAL SAFETY
TRAINING

A Case Study to be Submitted to the Journal of Safety Research

Jim Withers, Dr. Steven A. Freeman, Eunice Kim

Introduction

Global competition and rapidly changing technology have made employee training and retraining critical to an organization's productivity and long-term growth (Williams & Zahed, 1996). Providing employees with timely and meaningful training is essential in order for organizations to provide the necessary skills that will ensure performance. A 1991 study of corporate training policies and their implementation in five countries showed training has become a more important element of strategic planning and the highest levels of management are making training decisions (Talley, 2000; Dupont & Reis, 1991). Paradise (2007) reported that the total cost of employee training in the United States exceeds \$126 billion annually. Clearly, the financial stakes involved with implementing a training program are significant and demand that this be a key focus area for every organization.

Nowhere is the importance of providing high quality training more evident than in the area of employee safety training. The necessity of knowing how best to conduct safety

training was vividly brought to the general public's attention after the terrorist attacks of September 11, 2001, relative to the actions of emergency responders and their lack of training (Rudman, 2003). While health and safety training is globally recognized as a means of reducing costs associated with workplace injuries and illnesses (Overman, 2005), a study conducted by the National Institute of Occupational Safety and Health (NIOSH) and published in 2010 identified a surprisingly low number of high quality published studies looking at the effectiveness of safety training (Robson, 2010).

In the work environment, employee safety training is a key part of any organization's overall occupational safety and health program and mandated by a number of federal agencies, most notably the Occupational Safety and Health Administration (OSHA). OSHA's belief is that training is an essential part of every employer's safety and health program for protecting workers from injuries and illnesses (OSHA, 1998). For example, training of employees on the hazards of chemicals leads to the establishment of effective control methodologies, an essential component of any accident or exposure reduction strategy. Even though the Occupational Safety and Health Act (OSHA, 1970) does not specifically address the responsibility of employers to provide health and safety information and instruction to employees, Section 5(a)(2) requires that each employer "shall comply with occupational safety and health standards promulgated under this Act." (OSHA, 1998). Currently, the term "employee training" appears in more than 270 OSHA standards (Janicak, 1999). Every work environment has a unique set of potential hazards. Successful hazard mitigation strategies must necessarily include effective training.

Developing a safety training program that is effective is particularly challenging in an academic environment. High turnover rates are characteristic of this type of work environment where ironically “success” is partially measured by the numbers of people entering and leaving the institution (Talley, 2000). At Iowa State University (ISU), training is a key part of an overall organizational safety program. Specifically, the philosophy of safety training at ISU is stated as follows (Environmental, Health and Safety, 2005):

Training plays an important role in EH&S’ efforts to create a safe environment for the university community, while maintaining regulatory compliance.

Meeting safety and training requirements is a cooperative effort:

- Employees are responsible for performing their work in a safe and responsible manner. Knowledge of appropriate safe work procedures and safety rules is essential.
- Supervisors are responsible for providing and documenting the initial and continuing safety training necessary to allow employees to perform their work safely. This must include frequent work observations by the supervisor and prompt correction of unsafe work habits.
- Departments at Iowa State are responsible for meeting regulatory requirements, keeping work areas hazard-free, and ensuring that employees have completed all safety training requirements.

Based on the decentralized structure of the academic environment, flexibility in how safety training is offered is paramount. Essentially, it could be argued that flexibility is an integral part of evaluating the effectiveness of a safety training program and/or a particular course.

Model Background

To assist the safety professional, several organizations have developed guidance information on how to develop and evaluate training. The OSHA booklet entitled *Training Requirements in OSHA Standards and Training Guidelines* (OSHA, 1998) provides a model for the safety professional to follow when implementing a safety training program and includes the following steps:

- 1) Determining if Training is Needed
- 2) Identifying Training Needs
- 3) Identifying Goals and Objectives
- 4) Developing Learning Activities
- 5) Conducting the Training
- 6) Evaluating Program Effectiveness
- 7) Improving the Program

The American National Standard Institute (ANSI), a consensus organization, partnered with the American Society of Safety Engineers (ASSE) and published a guidance document entitled *Criteria for Accepted Practices in Safety, Health, and Environmental Training* (ANSI/ASSE, 2009) that identifies the following essential components of an effective training program:

- 1) Training Program Administration and Management
- 2) Training Development
- 3) Training Delivery
- 4) Training Evaluation
- 5) Documentation and Record Keeping

Finally, the National Institute of Occupational Safety and Health (NIOSH) (Cohen & Colligan, 1998), the research component of the OSH Act, lists the following as essential elements:

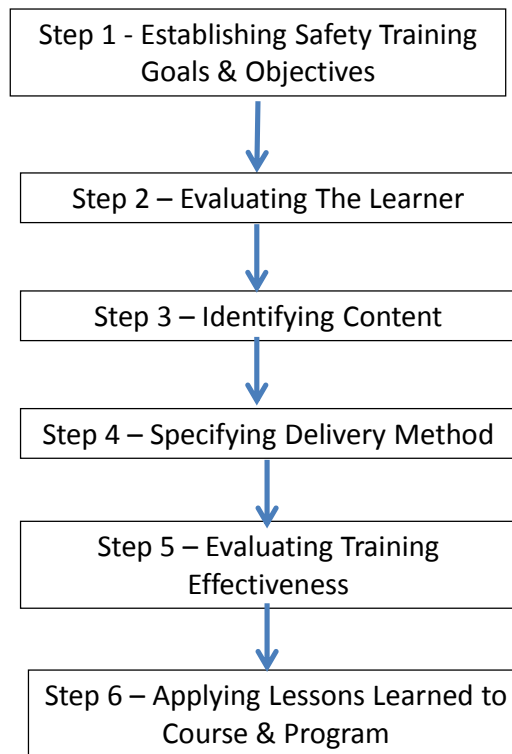


Figure 1 – Proposed Model for Development & Evaluation of Safety Training

- 1) Needs Assessment
- 2) Establishing Training Objectives
- 3) Specifying Training Content and Media
- 4) Accounting for Individual Differences
- 5) Specifying Learning Conditions
- 6) Evaluating Training
- 7) Revising the Training

A review of the OSHA, ANSI and NIOSH lists of essential elements shows many commonalities that can be synthesized into a model shown in Figure 1. The safety professional must give careful consideration to each individual step in the hierarchy in order to achieve the most effective training for each safety course.

Proposed Model

Given the information presented earlier and in consideration of issues associated with each step in Figure 1, how does the safety professional go about developing, implementing and evaluating safety training? A case study evaluation was conducted that focused on the functionality of the six-step process comprising the proposed model. Lessons learned from this evaluation would be of value to other safety professionals. Each step of the model was evaluated within the context of the most common type of safety training methodology and assessment technique: low-engagement, exam-based (Burke, 2006; Robson, 2010). The case study approach allowed for generation of both qualitative data that provided feedback on certain components of the model as well as quantitative data that shed light on specific questions of interest related to training effectiveness. The focus of the case study was an evaluation of a chemical safety course (*Laboratory Safety: Fundamental Concepts*) that was being offered both in classroom and computer-based formats. The course is the backbone of the University's chemical safety program and serves as a "roadmap" on chemical safety issues to the chemical users on campus. Topical areas covered were as follows: regulations, terminology, roles and responsibilities, exposure controls and prevention, recordkeeping, exposure monitoring, Material Safety Data Sheets (MSDS), emergency preparedness, Personal Protective Equipment (PPE) and lab maintenance and inspection. The course fits both the low-engagement and exam-based criteria. Figure 2 shows the correlation between each of the six steps of the model and the associated case study component. A discussion of each step follows:

Model Step	Case Study Component
Step 1 – Establishing Goals and Objectives	Convene expert panel consisting of subject matter experts.
Step 2 – Evaluating the Learner	Administer demographic survey during training
Step 3 – Identifying Content	Utilize expert panel feedback and convene focus group
Step 4 – Specifying Delivery Method	Develop data collection methodologies for both classroom and computer-based formats
Step 5 – Evaluating Effectiveness	Perform basic statistical analyses on accumulated data and interpret results
Step 6 – Applying Lessons Learned to Course and Programmatic Improvements	Apply results to specific course improvements and overall program improvements

Figure 2 – Proposed Case Study Model

Step 1 – Establishing Goals and Objectives

The first step in the development of the proposed model was to define a mechanism by which goals and objectives of the training could be established. On the ISU campus, there are two separate, multi-disciplinary safety offices (ISU, Ames Laboratory) each with a staff of safety professionals that have expertise in chemical safety. Specialists from both staffs were solicited to participate in an “expert panel” to help identify appropriate content. The panel’s primary duty was to discuss and agree upon key learning outcomes expected after completion of chemical safety training. The expert panel was a key part of completing Step 3 – Identifying Content as well.

Step 2 – Evaluating the Learner

In order to evaluate the learner, a survey mechanism was defined by which key learner characteristic data could be collected by participants in the study. A survey was devised after consulting the literature and identifying key characteristics that might have an impact on an evaluation of effectiveness of training. Survey experts on campus were also consulted. The survey was administered to both computer and classroom training participants in the study. Learner characteristics solicited were: age, gender, ethnicity, English proficiency, number of previous chemical safety training courses taken, number of years of experience working with chemicals, overall satisfaction with the training experience, and preferences on delivery method (computer versus classroom).

Step 3 – Identifying Content

As stated in Step 1, identifying appropriate chemical safety content was another task of the convened expert panel. As has been previously mentioned, the fundamentals course was an established course that covered a variety of chemical safety programmatic elements. During the course of establishing goals and objectives, the expert panel also engaged in the task of assessing the adequacy of content. Only the most important topics needed to be included in the training. The job of the expert panel was to come to a consensus on topics for inclusion in the training.

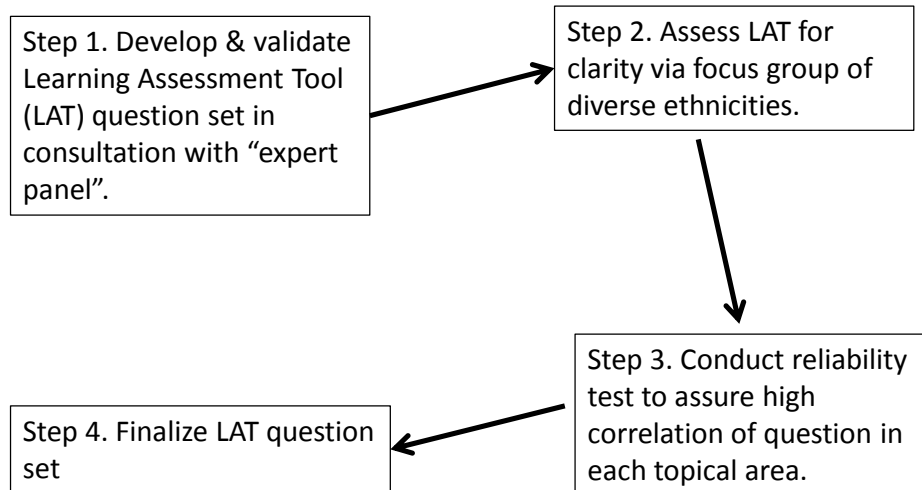


Figure 3 – Development and Validation of Data Collection Tool

Step 4 – Specifying Delivery Method

The laboratory fundamentals course was offered in two formats: classroom and computer-based. The classroom session was offered approximately three times per year; the computer-based version was available on-line via EH&S's training center 24 hours per day, 7 days per week. In order to accommodate a data collection mechanism, significant review and modification of the two delivery methods (computer, classroom) was necessary and is discussed in detail in Step 5 – Evaluating Effectiveness.

Step 5 – Evaluating Effectiveness

The evaluation of effectiveness is a significant and key element of the overall model.

Several questions were of interest relative to effectiveness:

- 1) Does the classroom and computer training provide an equivalent learning experience?
- 2) Are there any learner characteristics that affect amount of learning?
- 3) How much chemical safety information is retained after 1 year?

In order to collect data on these questions, a pre-test/post-test format was utilized that was similar to a study conducted by Williams & Zahed (1996). The characteristic survey described in Step 2 – Evaluate the Learner was used to look at question 2. Figure 3 shows the sequence of steps involved in first developing and then validating a data collection tool.

The convened expert panel again played a critical role. A discussion of each of the four steps is as follows:

Development and Validation of Data Collection Tool

To accommodate the necessary data collection mechanism, a Learning Assessment Tool (LAT) was developed. Developmental steps were as follows:

Step1: Develop LAT in Consultation with Expert Panel. A total of 16 relevant topical areas were identified by the expert panel for inclusion in the LAT. To accommodate the necessary pre- and post-test strategy (described below), three different version of the LAT were developed. Since each version contained 16 questions, it was

necessary to develop and validate a master question set totaling 48 questions (3 questions per topical area).

Step 2: Assess LAT for Clarity. To ensure clarity and in recognition of the ethnically diverse nature of the participants, the master question set was first given to a multi-cultural focus group for review. The focus group was asked to read each question and provide feedback on issues of clarity, wording and question structure. The demographics of the focus group included reviewers who had English as a second language and were proficient in one of the following languages: Chinese, English, Russian, or German. The focus group provided feedback on the LAT questions and identified terminology that was confusing or unclear. Focus group comments received were incorporated into the final question sets for the LAT.

Step 3: Conduct Reliability Test. The LAT was next administered to approximately 20 individuals who had completed chemical safety training previously. A correlation analysis was done using a multivariate test (Wilk's' Lambda test statistic) to determine how well each of the 3 questions tested the student on a particular learning outcome. It was anticipated that there would be a high correlation of successful responses to each of the 3 questions for a given topical area assuming knowledge of that learning outcome.

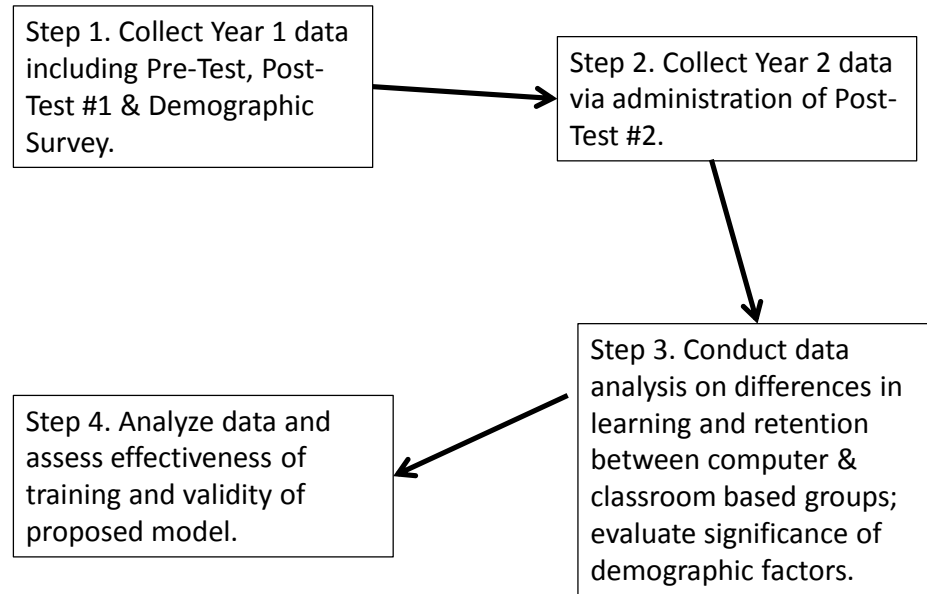


Figure 4 – Data Collection and Analysis

Step 4: Finalize LAT. The results of the correlation analysis were then used to finalize the LAT prior to the beginning of the data collection phase of the study. Questions with lower correlation results were further evaluated for clarity. The 48-question validated LAT was then divided into 3 individual versions of the LAT.

Data Collection and Analysis

The second component of this step of the model was the actual collection and analysis of the data. The sequence of steps for data collection has been briefly discussed already and is shown in Figure 4.

Step 1: Collect Year 1 Data. The LAT was administered prior to and after training. In the classroom sessions, the pre-test and post tests were handed out to students. In the computer-based sessions, the pre and post-tests were presented to the student automatically on the computer. In each case, the version (1, 2 or 3) was randomly selected either by the instructor or computer program. Upon completion of the course, a second and different version of the LAT was administered. Participants were introduced to the study via presentation of an informational memo.

Those agreeing to participate were asked to complete the learner characteristic survey described earlier.

Step 2: Collection of Year 2 Data. Study participants were tracked and upon the 1-year anniversary date of completion of training, they were requested to complete and return the third version of the LAT.

Step 3: Conduct Data Analysis. After all tests and surveys were collected for each participant, tests were corrected. The difference between pre and post-course exam scores (as measured by number of questions correct) was interpreted as a measure of the amount of learning resulting from course participation. For participants in the second phase of the study, the difference between the first post-test and the second was interpreted as a measure of retention of the course material. Summary data was generated using the statistical functions in Excel. Group comparisons were done using t-tests and an analysis of variance (ANOVA) model. The issue of question and exam

difficulty was evaluated using a calculated difficulty factor; the issue of order of administration was evaluated using an ANOVA model.

Step 6 – Applying Lessons Learned to Course and Programmatic Improvements

The results generated from the evaluation of the proposed model will be synthesized into an overall discussion of lessons learned in the Summary and Conclusions section.

Case Study Results & Discussion

The overall goal of the case study was to evaluate lessons learned from use of the proposed model. In the form of a research question, the goal would be as follows:

Evaluate lessons learned from the use of a proposed model for developing and evaluating training.

As was stated earlier, the context of the case study was a chemical safety training course offered in both a classroom and computer-based format (low-engagement, exam-based). Lessons learned information was gleaned from each step of the model.

Depending on the organization and the size of the safety office staff, the process of establishing essential learning outcomes (Step 1) and course content (Step 3) may be done unilaterally by the trainer (generally a subject matter expert) or as a collaborative effort by several safety professionals with relevant expertise. The presence of two separate, multi-disciplinary safety offices on the ISU campus made it easy to assemble a

group of subject matter experts all of whom have a vested interest in effective chemical safety training. The panel communicated via regular e-mails and met on four occasions to discuss pertinent issues related to developing several of the model components.

The first issues the panel had to wrestle with were identifying the appropriate learning outcomes (Step 1) and associated course content (Step 3). With an exam-based format, this first came down to a process of defining the most essential topics to be covered. Each discipline specialist brought their own professional and personal experiences to bear on this endeavor. For example, a specialist with an emphasis in waste management lobbied to have two LAT questions dealing with that topic. However, the rest of the panel disagreed citing the fact that waste management information is adequately covered by another training course and, therefore, devoting two (out of 16) questions to that topic was unnecessary. Another interesting benefit of this peer-to-peer, interactive process was the building of a collective understanding of what the true programmatic requirements were in specific areas. For example, the expert panel had different understandings of what the site-wide procedures were for handling medical emergencies. A review of salient documentation (e.g., safety manuals, web site information) uncovered discrepancies on how that information was presented. So, an unintended benefit of identifying key learning outcomes was the clarification of safety program information accessed by employees.

Once the panel had agreed on appropriate content and an initial set of associated questions for the LAT, it was time to consider the learner (Step 2). The first element of

Focus Group Comments	Corrective Action
What does the word “strive” mean?	Restructured question; use alternate word
“Deficiencies” is a difficult word.	Restructured question; use alternate word
What is a “dip and read test”?	Used a different example in question
Add the word “University” to “Department” to avoid confusion.	Change made
Give an example of a “chemical exposure”.	The example of a skin burn was added to question
Replace “substituting less hazardous chemicals into the process” with “using a less hazardous chemical”.	Change made
Replace the word “occupant” with “workers or employees”.	Change made
Replace “responsible parties” with “responsible people”.	Change made
What is a “secondary container”?	Examples of secondary containers added
Use the phrase “labeling of container” rather than “container labeling”	Change made

Figure 5 – Focus Group Comments and Associated Corrective Actions

this step involved testing of the LAT. This process included collaboration with a focus group composed of individuals from a variety of ethnicities that spoke English as a second language. This became an eye-opening experience for some members of the expert panel as each considered the feedback received. Figure 5 provides a summary of focus group comments and the associated corrective actions. As can be seen, most of the comments received dealt with word usages. Some members were surprised that words like “strive”, “exposure” and “occupant” were deemed difficult to understand. Other subtle phrasing issues were noted on important chemical safety topics such as the recommendation to use the phrase “labeling of container” in a particular questions rather

than “container labeling”. Regardless of perceptions by the expert panel, the feedback received resulted in a better assessment technique via better, more clear questions on the LAT.

The subsequent reliability testing of the LAT provided additional information on the adequacy of the questions as distributed to the three versions. The Wilk’s’ Lambda test statistic was used to determine question consistency. In other words, if the three questions were clearly written and the participant had salient knowledge of the topic, all questions should be answered correctly. Conversely, in a situation where the participant did not have knowledge of the concept, all three questions would be answered incorrectly. Question set analysis revealed 3 of the 16 topical areas that had one of three questions that were not consistently answered correctly relative to the other two. The three discrepancies were in the areas of training records, regulations and laboratory audits. A review of the individual questions did not reveal any apparent issues with clarity (as described before) that would warrant restructuring of the question. This information was used to review the content of both versions (computer and classroom) to ensure that it was being clearly delivered prior to the commencement of the study. The ultimate benefactor of the process of reviewing question content and testing reliability was the training participant.

Another component of the study, development of a learner characteristic survey, was related to Step 2 – Evaluating the Learner. As stated previously, the survey was devised after consulting the literature and identifying key characteristics that might have an

impact on an evaluation of effectiveness of training. The administration of the survey as a part of the classroom training sessions was very straightforward and was preceded by an introduction to the study. Administration of the survey during the computer-based training involved some programming by instructional technology but was also a fairly straightforward endeavor. On the computer, the participant was introduced to the study and then given a link to the survey.

With the development and testing of the LAT and the availability of learner characteristic data, several specific questions of interest related to the effectiveness of the two delivery methodologies (Step 5 – Evaluating Effectiveness) could now be examined. On the issue of learning experiences, an analysis of the pre and post-test data indicated that there was no significant difference in the amount of learning between the computer group and the classroom group. The practical conclusion from this data is that the two delivery methods, classroom and computer, provide equivalent learning experiences for participants.

Given the diverse population found on a college campus, the role of learner characteristics and learning was also examined. Specifically, to see if any of the characteristic data collected could help explain the amount of learning, the measured amount of learning was tested against the learner characteristic data gathered via the survey. An analysis of the data showed that there were no significant characteristics that might explain the amount of learning observed in either the computer or classroom groups.

A final question that was evaluated was related to retention of chemical safety information after one year. Statistical analyses similar to those used to evaluate learning were performed. Results showed that there were no significant differences in the amount of information lost after one year between the classroom and computer groups.

The data allowed exploration of additional issues also related to Step 5 (Evaluating Effectiveness) that are critical given the chosen assessment technique (low-engagement, exam-based, pre and post-test format): question and exam difficulty. In general, a 70% pass rate is widely accepted as an indicator of “moderate knowledge”, 80% of moderately higher knowledge, and so forth (Angoff, 1984). In order to assess the adequacy of that performance level, question and exam difficulty must be considered. An analysis of the difficulty of each question and exam suggested that Version 2 was more difficult than the other two. Another variable examined was order of exam administration. Data collected showed that participants taking Version 2 as a pre-test and either version 1 or 3 as a post-test showed the greatest increase in learning of all possible combinations. A possible explanation of this observation is that participants scored low initially on Version 2 because of increased difficulty. The combination of the difficulty and order of exam data suggest that Version 2 was a more difficult LAT than either Version 1 or 3. Clearly, this information is important relative to evaluating effectiveness as measured by amount of learning.

Summary & Conclusions

Consideration of the accumulated results is necessary in order to complete Step 6 of the proposed model: Applying Lessons Learned to Course and Programmatic Improvements. So what do the results of this study indicate about the validity and usefulness of the proposed model and how can they be applied to course and programmatic improvements?

The contributions of the expert panel to this study cannot be understated and were a key component of the effectiveness of the proposed model. In the area of establishing goals and objectives (Step 1) and appropriate content (Step 3), it is recognized that not all safety professionals will have access to a group of discipline specialists. On a college campus with a multi-disciplinary safety office, the approach used in this study was ideal. Companies with multiple facilities may have a “local” safety office that consults with the corporate safety office which would allow a similar type of collaboration. In a small company with a single safety professional, other means of peer input must be sought out. Industry peer groups and safety professional e-mail distribution lists are two sources of peer input that can assist in the review of goals and objectives. The collaborative, peer-to-peer process of identifying goals and objectives used in this study provided validity to the model. The different experiences and perspectives brought to the table by each safety professional not only resulted in identification of the most important content needed but also served as a forum for determining “success”. The peer review component of the proposed model, as shown by the expert panel in this study, was highly valuable and resulted in a more effective chemical safety training course.

The data generated by the model allowed for serious consideration of the learner (Step 2). This is absolutely essential for ensuring that safety training is effective. The development and testing of the LAT ensured that exam questions were clear. As was stated, the expert panel members were, in some cases, surprised at the feedback from the focus group. Ensuring question clarity will result in the assessment technique being a more accurate indicator of learning. The learner characteristic survey allowed for collection of data and an evaluation of any influence on learning (Step 5 – Evaluate Effectiveness). The survey was developed in consideration of salient literature and the unique work environment (college campus). The content of the survey, however, can be adapted by the safety professional to any circumstance. The characteristic data may have a significant influence on course and programmatic improvements.

The data collection mechanisms devised for this study were straightforward and relatively easy to implement. Being able to show equivalent learning experiences between the two delivery methodologies was a key part of validating the efficacy of the two delivery methodologies. The data generated can now be used to support programmatic decisions related to how the course is offered. For example, the number of classroom sessions offered may need to be reduced due to time constraints of the instructor. Data showing equivalent learning experiences can be used to support that change.

The retention was another key area of interest in safety training and an additional part of Step 5 of the model. The minimal loss of chemical safety knowledge over the course

of a year is noteworthy and can have significant programmatic implications (e.g., allowing for alternative means of verifying on-going competency via mechanisms like a challenge exam). However, programmatic changes like this can only be made with supporting data. The straightforward mechanisms used in this study allowing for collection and analysis of data of retention can serve as an example for others.

Finally, the study showed the importance of examining issues related to question and exam difficulty as an additional component of Step 5. Without an understanding of difficulty, the impact and value of the safety training is difficult to determine. Management might look at the high rate of safety training completion and falsely conclude that workers, because of participation in safety training, are now “qualified” when, in reality, the assessment technique did not have sufficient rigor. Conversely, the safety professional might look at low pass rates for a given safety course and conclude that some aspect of the course (e.g., content) needs improving when, in reality, the assessment technique used was too difficult.

Recommendations for Future Research

It is easy to understand how methods for evaluating the effectiveness of the training might be minimal or, in some cases, non-existent. Not too long ago, the safety professional would buy a commercially available, generic safety training video, show it to a group of employees, have each participant complete a sign-off sheet and call the training “complete”. The availability of new technologies like the computer has provided additional options for delivery of training. Accordingly, a limited number of studies of

training effectiveness have been reported in the scientific literature (see Robson, 2010). Another contributing factor as to why safety training courses and programs in general are not adequately evaluated is the safety professional's lack of knowledge and experience related to program assessment. Vojtecky & Schmitz (1986) cited both lack of interest and lack of training in program evaluation as reasons why rigorous safety training effectiveness is not done. Still, the costs of not evaluating the effectiveness of safety training can be substantial in terms of lost opportunities to improve training and potentially further reduce injuries and illnesses. In fact, only about 50% of companies measure learning outcomes from training, and less than 25% make any attempt to assess potential programmatic improvements resulting from training (Sugrue & Rivera, 2005).

The safety professional may view evaluation of training effectiveness as a daunting task. However, the proposed model evaluated in this study was straightforward. The associated data collection mechanisms and analysis techniques were also straightforward. Yet, the information provided is extremely valuable and can be used to enhance the effectiveness of the overall training experience. The process of utilizing resident subject matter experts to define learning outcomes and specify course content ensured that participants were receiving the most important information. The collection of learner characteristic data provided a "profile" of the typical participant and will be considered when evaluating future enhancements of the course. Organizations that use a pre and post-test format as an assessment technique will benefit from the mechanisms proposed to evaluate question and exam difficulty. The data collection and analysis techniques used to confirm that learning is occurring and that significant retention of training content

occurs after one year may have significant programmatic implications. Most organizations are continually evaluating ways to reduce costs; the data generated by the mechanisms of the proposed model will allow the training program to be a part of that evaluation.

In conclusion, the intent of this study of the proposed model was to remind the day-to-day safety practitioner of the importance of evaluating training effectiveness and also to suggest several straightforward techniques that can be considered and used to accomplish that task. An even more compelling case for the need to evaluate safety training effectiveness is made by NIOSH (Robson, 2010, pg. 1):

Research on the effectiveness of Occupational Health and Safety (OHS) training is needed to: 1) identify major variables that influence the learning process and 2) optimize the allocation of resources for training interventions. In research on training, it is often difficult to arrive at definitive conclusions about effectiveness. Typically, many workplace characteristics contribute to real-world effects of training. Designing studies that validate the unique contribution of individual factors, such as specific training program features, are often infeasible. Traditional narrative literature reviews of training are often speculative about specific factors that enhance the relative effectiveness of OHS training interventions in reducing occupational injuries, illnesses and deaths.

It should be clear from the above quote that much remains to be learned about the topic of safety training effectiveness. The evaluation and reporting of information learned during evaluation of training must not be limited to researchers in the world of academia. The day-to-day safety practitioner will need to play a role in studying these key issues. It is hoped that the model proposed and evaluated in this study will serve as a

catalyst for other safety professionals to join in a discussion about training effectiveness.

The ultimate benefactor will be the worker receiving safety training.

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CHAPTER 3

**LEARNING & RETENTION OF CHEMICAL SAFETY TRAINING
INFORMATION: WHAT THE LEARNER CAN TEACH THE SAFETY
PROFESSIONAL**

A Paper to be Submitted to Chemical Health and Safety (Elsevier Publishing)

Jim Withers, Dr. Steven A. Freeman, Eunice Kim

Introduction

Employee safety training is a key part of any organization's overall occupational safety and health program and is mandated by a number of federal agencies, including the Occupational Safety and Health Administration (OSHA). Many resources are available to the safety professional when putting together a safety training course or program (NIOSH, 1998; OSHA, 1998; ANSI/ASSE, 2009). A synthesis of the approaches suggests the developmental process shown in Figure 1.

In order to truly evaluate the effectiveness of any safety training intervention, consideration of each step in the process must be done. In some cases, the safety professional might delve into subject matter that is perhaps unfamiliar. The importance of conducting this evaluation, however, cannot be understated. The results may have a

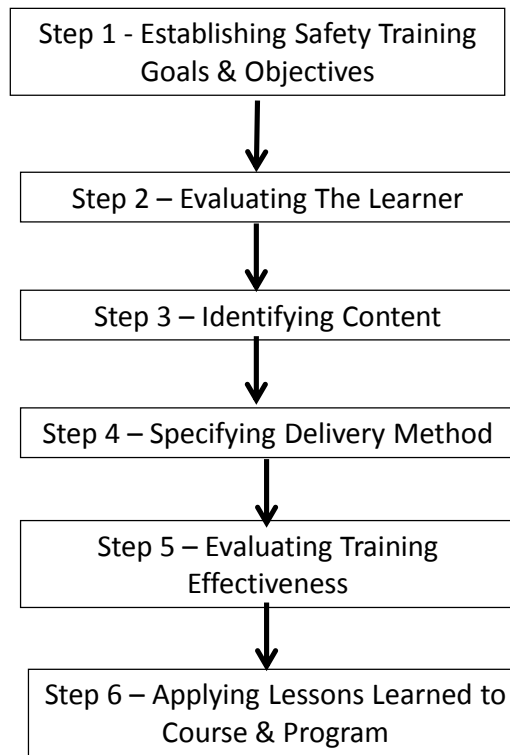


Figure 1 – Proposed Model for Development & Evaluation of Safety Training

potentially significant impact on not only training effectiveness, but the overall quality of the worker safety and health program as shown by indicators such as the number of accidents or injuries.

Step 1 - Establishing Safety Training Goals & Objectives

The first step in devising an effective safety training course is to define the desired goals and objectives. What should the student be able to demonstrate upon completion of the training? Is demonstration of knowledge of a particular organizational procedure via written exam the desired outcome? Perhaps demonstration of the proper use of a fire

extinguisher to put out a simulated fire is the desired goal of a successful training course. In a recent literature review funded by NIOSH, four categories of learning outcomes were identified: knowledge (typically shown via a written exam covering a particular policy, procedure or hazard), attitudes & beliefs (including perception of risk), behaviors (meaning worker actions that could result in exposure to hazards) and health (referring to early detection of illnesses/injuries) (Robson et al., 2010). Knowledge, as shown by successful completion of a written exam, is a common measure of effectiveness in safety training (Burke, 2006). At Iowa State University, the majority of safety training courses have demonstration of knowledge via successful completion of a written exam as the identified goal or objective. Equally important to the safety professional is retention of the information received in training which is related to the requirement for refresher training when hazards change or at some prescribed frequency (typically annually). The OSHA Bloodborne Pathogens standard (OSHA, n.d.) is an example of a regulation with a mandatory annual refresher training requirement.

Step 2 - Evaluating The Learner

The safety professional must consider the potential impact of characteristics of the learners taking the same safety training course in order to deliver the best safety training. For example, Kirsch et al. (2007) recently reported that literacy amongst the U.S. workforce is eroding and will continue to do so until 2030. In this context, it might be concluded that a verbal presentation of safety information is more effective than a written presentation. Gronbacher (2005) conducted a marketing survey of safety professionals and found that boredom was the greatest obstacle to effective training! A preponderance

of younger workers might argue for a more engaging, computer-based safety course.

Umbrell (2005) reported that some global workforces have as many as five generations of workers, each with differing cultural and education backgrounds, who share the same safety training program! Despite the complexities suggested by the previous examples, it clearly behooves the safety professional to give some consideration to the characteristics of learners when devising a training course.

Step 3 - Identifying Content

Most OSHA regulations with training requirements offer specific information on the required content. As an example, OSHA's Occupational Exposures to Chemicals in Laboratories (29 CFR 1910.1450) regulation has several very prescriptive training requirements (e.g., 3 (iii) – Location and availability of the Chemical Hygiene Plan). Other training requirements, however, are open for interpretation in terms of required content (e.g., (C) The measures employees can take to protect themselves from these hazards, including specific procedures the employer has implemented to protect employees from exposure to hazardous chemicals, such as appropriate work practices, emergency procedures, and personal protective equipment to be used). Depending on the organization and the size of the safety office staff, the process of establishing identifying essential course content may be done unilaterally by the trainer (generally a subject matter expert) or as a part of collaborative effort by several safety professionals with relevant expertise.

Step 4 - Delivery Method

In the previous examples of OSHA-mandated training, the content of the training was specified but no particular methodology for instruction or criteria for demonstration of knowledge was given. In fact, OSHA leaves these details to the employer. Burke (2006) classified levels of training engagement as low, moderate and high. Lectures are an example of low engagement or “passive” training that are “commonly used to present health- and safety-related information” (Burke, 2006, p. 315). Moderately engaging techniques include demonstration of knowledge via a feedback mechanism that allows the student to correct their own mistakes through feedback from the instructor or, in the case of a computer-based training method, via feedback from the course. Highly engaging training involves a modification of behavior. Which method is best for a given safety course is determined by a variety of factors including learning preferences of the students, teaching preferences of the trainers, organizational goals and available resources (Coppola and Myre, 2002).

Classroom Versus Computer-Based Instruction

The emergence of computer technology has led to extensive use of this delivery method for safety training. Today, there is widespread availability of off-the shelf computer-based training courses from a variety of vendors. Accordingly, extensive research on the effectiveness of classroom versus computer-based training has been conducted and reported in the literature.

Traditional lecture (classroom) instruction has many advantages over other methods including opportunity for discussion and interaction, dissemination of large amounts of information to a large number of people in a short period of time, greater control over whether students finish a course, ease of course development, ability of instructors to motivate students to learn and perform, and wide acceptance as an approach to teaching (Yoder & Heneman, 1977; Hasselbring, 1986; Ganger, 1990; Harrap, 1990; Della-Guistina & Deay, 1991). Potential weaknesses of traditional classroom instruction include passive listening, limited trainee involvement, limited effectiveness of skill acquisition, limited skill and effectiveness of the trainer, diminished control over relevance of material presented, limited or fixed time for presentation and limited individual attention or instruction (Gery, 1987; Griffin, 1989; North, 1989; Myers, 1990).

Advantages of computer-based instruction have also been well documented and include increased accessibility, individualized self-paced instruction, automated recordkeeping, control of the training process, not subject to the skills and availability of an instructor, potential for reduced training time, program interactivity, timely and targeted feedback and reinforcement, individualized instruction, reduced likelihood of error in presentation of content, and consistency in presentation (Goldstein, 1980; Schaab & Byham, 1985; Schwade, 1985; Ladd, 1986; Pipeline & Gas Journal Staff, 1988; Furgang, 1989; Forlenza, 1995). Developmental costs have been previously discussed, but several studies have suggested that long-term benefits may outweigh costs (Reynolds, 1982; Heck, 1985; Knight, 1988; Perez & Willis, 1989). Other disadvantages discussed

in the literature include computer phobia and anxiety (Banks & Havice, 1989) and lack of acceptance by instructors (Stemmer, Nolan, & Culler, 1983).

Step 5 - Evaluating Safety Training Effectiveness

Evaluating the effectiveness of safety training is critical. Sugure & Rivera (2005) report, however, that only about 50% of companies measure learning outcomes from training, and less than 25% make any attempt to assess potential programmatic improvements resulting from training. The National Institute for Occupational Safety and Health (NIOSH) makes a compelling case for the need to evaluate safety training effectiveness (Robson et al., 2010, page 1):

Research on the effectiveness of Occupational Health and Safety (OHS) training is needed to: 1) identify major variables that influence the learning process and 2) optimize the allocation of resources for training interventions. In research on training, it is often difficult to arrive at definitive conclusions about effectiveness. Typically, many workplace characteristics contribute to real-world effects of training. Designing studies that validate the unique contribution of individual factors, such as specific training program features, are often infeasible. Traditional narrative literature reviews of training are often speculative about specific factors that enhance the relative effectiveness of OHS training interventions in reducing occupational injuries, illnesses and deaths.

Given the prevalence of safety training provided via multiple delivery methods (computer and classroom), research has been conducted on both learning and retention.

Learning

Differences in demonstrated learning between classroom and computer based instruction have been studied extensively across many disciplines including safety.

Lawson (1999) evaluated a group of 46 college students who were receiving OSHA blood borne pathogen training via either CBT or the classroom. Students were administered a 30-question, multiple-choice pre-test and post-test (upon completion of training). The results indicate that CBT students scored higher on a post-test administered immediately after training than instructor-led students (an average of 85.7% for CBT versus 64.7% for instructor-led). In the more specific area of chemical safety, Williams and Zahed (1996) looked at 54 employees of a chemical processing plant who received chemical hazard communication training via CBT or classroom. Their results indicate that there was no difference in learning (as indicated by a post-test) immediately after completion of the training.

Retention

The amount of retention occurring between classroom and computer-based instruction has also been reported in the literature. Lawson (1999) studied learning and retention in a group of 46 college students. Students were administered a 30-question, multiple-choice pre-test and post-test (upon completion of training). Another 30-question post-test was given three weeks later. Results indicated that both groups experienced a similar amount of decrease in test scores after 3 weeks. Booker, Catlin & Weiss (1991) administered a follow up test and questionnaire one year after initial training to a group of 114 asbestos workers and found that retention was better on specific work practice questions than those dealing with other issues. Their results provided an opportunity to assess the original training but the study was not designed as an evaluation effort. Williams and Zahed (1996) noted that retention of chemical hazard communication

information after one month was higher for students taking computer-based training than for classroom instruction (85.30% test scores on CBT versus 78.74% for instructor-led). Interestingly, a NIOSH review of recent literature (1996 to present) identified very few studies of safety training that evaluated long term retention and no studies in the chemical safety arena (Robson, 2010).

Step 6 – Applying Lessons Learned to Course & Program Improvements

Despite the many demands on the safety professional's time, regular review of the training program and specific training courses is imperative. Are there differences in the amount of learning between the two delivery methods? Are there certain learner characteristics that affect amount of learning? There are a myriad of questions that can be evaluated via a comprehensive assessment of safety training effectiveness. Ultimately, this evaluation leads to better safety training.

Research Objectives

Given the widespread use of computers as a delivery method and the prevalence of low-engagement, exam-based formats for safety training courses, a large scale research study was conducted that evaluated the effectiveness of a site-wide chemical safety training course. The following research questions were defined:

Evaluate levels of learning between trainees receiving chemical safety instruction via computer-based training versus classroom instruction.

In addition, learner characteristic data were collected and analyzed for any impact on effectiveness as measured by amount of learning as demonstrated by performance on a written exam. An associated second research question is as follows:

Evaluate the impact of a variety of characteristics on learning and retention between trainees receiving chemical safety instruction via computer versus classroom instruction. Specifically, data was collected on age, gender, ethnicity, English language proficiency, amount of previous experience working with chemicals, number of chemical safety courses taken previously, overall satisfaction with training and delivery method preferences.

Finally, an analysis of the amount of retention occurring after 1-year was also assessed. The associated research question is as follows:

Evaluate levels of retention of chemical safety information after 1 year by trainees receiving computer-based training versus classroom instruction.

The results of the study were used to identify lessons learned that could be applied to programmatic and course improvements. An additional purpose was to demonstrate simple techniques that can be used or adapted for use by other safety professionals when evaluating the effectiveness of a low-engagement, exam-based safety training course.

Materials & Methods

Specific steps in the study methodology were defined in conjunction with the six-step model shown in Figure 2. A brief description of each step and the associated research component is as follows:

Step 1 – Establishing Goals and Objectives

Goals and objectives of the training were established by a convened “expert panel” comprised of chemical safety specialists on campus. The primary learning outcome of the training was demonstrated knowledge via a written exam on the following programmatic elements: pertinent OSHA requirements, roles and responsibilities of chemical users, how to obtain Material Safety Data Sheets (MSDSs), requirements for container labeling,

Model Step	Research Component
Step 1 – Establishing Goals and Objectives	Convene expert panel consisting of subject matter experts.
Step 2 – Evaluating the Learner	Administer demographic survey during training
Step 3 – Identifying Content	Utilize expert panel feedback and convene focus group
Step 4 – Specifying Delivery Method	Develop data collection methodologies for both classroom and computer-based formats
Step 5 – Evaluating Effectiveness	Perform basic statistical analyses on accumulated data and interpret results
Step 6 – Applying Lessons Learned to Course and Programmatic Improvements	Apply results to specific course improvements and overall program improvements

Figure 2 – Proposed Research Model

how to select appropriate Personal Protective Equipment (PPE), procedures for handling emergencies, and procedures for handling workplace events such as an accident.

Step 2 – Evaluating the Learner

In order to evaluate the learner, a survey mechanism was defined by which key characteristic data could be collected by participants in the project. Specific demographic characteristics were: age, gender, ethnicity (White (non-Hispanic), Black (non-Hispanic), Hispanic, Native American, Asian), English proficiency (beginner, moderate, proficient, highly proficient), education level (high school diploma, some college, 2-year degree, 4-year degree, Master's, Ph.D./Ed.D.) , number of previous chemical safety training courses taken (0, 1, 2, 3 or more), number of years experience working with chemicals (0, 1, 2, 3 or more), overall satisfaction with the training experience (very satisfied, somewhat satisfied, somewhat dissatisfied, very dissatisfied) and preferences on delivery method (computer versus classroom).

Step 3 – Identifying Content

Identifying appropriate also was the task of the convened expert panel. During the course of establishing goals and objectives, the expert panel also engaged in the task of assessing the adequacy of content. Only the most important topics needed to be included in the training. The job of the expert panel was to come to a consensus on identifying those topics for inclusion in the training.

Step 4 – Specifying Delivery Method

The chosen chemical safety training laboratory fundamentals course was already being offered in two formats: classroom and computer-based. However, to accommodate

a data collection mechanism, significant review and modification of the two delivery methods (computer, classroom) was necessary and is discussed below.

Step 5 – Evaluating Effectiveness

To collect data on learning, a pre-test/post-test format was utilized that was similar to a study conducted by Williams & Zahed (1996). Specifically, the difference between pre and post-course scores on a 16-question Learning Assessment Tool (LAT) was interpreted as a measure of amount of learning. To accommodate the necessary pre- and post-test strategy, three different versions of the LAT were developed. Since each version contained 16 questions, it was necessary to develop and validate a master question set totaling 48 questions (3 questions per topical area). The LAT version administered as the pre-test was randomly selected; the post-test was a different, randomly selected version of the LAT. Individual questions were tested to ensure strong correlation within each subject matter. The learner characteristic survey discussed previously in Step 2 was also administered after completion of the course. Data analysis on differences in learning consisted of a variety of t-tests and analysis of variance (ANOVA) models.

Step 6 – Apply Lessons Learned to Course and Programmatic Improvements

Data collected was synthesized into an overall assessment of effectiveness that included suggestions for future improvements. This information is included in the Results & Discussion sections as well as the Summary & Conclusions sections.

Results & Discussion

The following results and discussion are presented within the context of the pertinent research question.

Evaluate levels of learning between trainees receiving chemical safety instruction via computer versus classroom instruction.

To assess the differences in learning between the two populations as a whole, the mean difference between pre and post-course Learning Assessment Tool scores (as measured by the increase or decrease in number of questions correct out of 16 questions) was calculated (Delta 1). A t-test analysis was conducted comparing the two population means for Delta 1 and is shown Table 1. The -1.23 result indicates that the difference between the two increases is not significant. The practical conclusion from this data is that the two delivery methods, classroom and computer, provide equivalent learning

Delivery Method	Mean (95% Confidence Interval)	Standard Deviation	T-statistic
Classroom (n = 92)	1.40 (0.91, 1.89)	2.38	-1.23 (df=204; p=0.22)
Computer (n = 151)	1.80 (1.38, 2.2)	2.63	

Table 1 – T-test Analysis of Average Increase in Exam Score (Delta 1)
as Measured by Number of Questions Correct
(Difference in Pre- and Post-Test Score)

equivalent learning experiences for participants. Implications of this finding are discussed in the Summary and Conclusions section.

Evaluate the impact of a variety of characteristics on learning between trainees receiving chemical safety instruction via computer versus classroom. Specifically, data was collected on age, gender, ethnicity, English language proficiency, amount of previous experience working with chemicals, number of chemical safety courses taken previously, overall satisfaction with training and delivery method preferences.

Given the availability of learner characteristic survey data, a more detailed evaluation of learning differences between the two populations was possible. Basic summary statistics are shown in Table 2. A total of 92 participants took training in the classroom; 151 participants completed training on the computer. Age distribution data were stratified into seven categories and show that the majority of participants in both delivery method groups were in either age 20- 24 or age 25-30 groups (classroom = 80%; computer = 64%) . This is not surprising and reflective of the fact that most of the study participants were students at Iowa State University (ISU). The gender breakdown for each delivery method was unremarkable with a male/female split of 66%/34% for the classroom participants and 54%/48% for the computer. Certain ethnic categories were not able to be analyzed due to lack of data (e.g. no Native American participants in either type of training; no Hispanic participants in classroom delivery). In terms of English proficiency, there were low total numbers of participants that rated themselves as either a “beginner” or as having “moderate” proficiency. This is perhaps a function of ISU

Characteristic	Classroom		Computer	
Age	<19 – 5 (5%)	41-50 – 0	<19 – 12 (8%)	41-50 – 10 (7%)
	20-24 – 53 (58%)	51-65 – 5 (5%)	20-24 – 71 (47%)	51-65 – 7 (5%)
	25-30 – 20 (22%)	>65 – 0	25-30 – 26 – (17%)	>65 – 0
	31-40 – 8 (9%)		31-40 – 25 (16%)	
Gender	Male – 61 (66%)	Female – 31 (34%)	Male – 79 (52%)	Female – 72 (48%)
Ethnicity	White (Non-Hispanic) - 58 (63%)	Native American – 0	White (Non-Hispanic) – 115 (76%)	Native American – 0
	Black (Non-Hispanic) – 5 (5.4%)	Asian – 29 (32%)	Black (Non-Hispanic) – 5 (3%)	Asian – 24 (16%)
	Hispanic - 0	Other - 0	Hispanic – 4 (3%)	Other – 3 (2%)
English Proficiency	Beginner – 0		Beginner – 4 (3%)	
	Moderate – 8 (8.6%)		Moderate – 3 (2%)	
	Proficient – 27 (29%)		Proficient – 31 (20%)	
	Highly Proficient – 57 (62%)		Highly Proficient – 113 (75%)	
Educational Profile	High School - 6 (7%)	4-Year – 33 (36%)	High School – 7 (5%)	4-Year – 49 (32%)
	Some College – 23 (25%)	Master's – 19 (21%)	Some College – 38 (25%)	Master's – 27 (18%)
	2-Year – 1 (1%)	Ph.D./Ed.D. – 11 (9%)	2-Year – 4 (3%)	Ph.D./Ed.D. – 26 (17%)
Prior Chemical Safety Training	0 courses – 25 (27%)	2 courses – 14 (15%)	0 courses – 34 (23%)	2 courses – 19 (13%)
	1 course – 35 (38%)	3 or more - 18 (20%)	1 courses – 35 (23%)	3 or more – 53 (35%)
Years Experience	0 years – 28 (30%)	2 years – 29 (19%)	0 years – 45 (30%)	2 years – 29 (19%)
	1 year – 22 (24%)	3 or more years – 28 (30%)	1 year – 12 (8%)	3 years – 65 (43%)
Overall Satisfaction	Very satisfied – 62 (67%)	Somewhat dissatisfied – 2 (3%)	Very Satisfied – 45 (30%)	Somewhat dissatisfied – 14 (9%)
	Somewhat satisfied – 28 (30%)	Very dissatisfied - 0	Somewhat satisfied – 76 (50%)	Very dissatisfied – 2 (1%)
Delivery Method Preference	Classroom – 52 (57%) Computer – 38 (42%) Either - 2		Classroom – 14 (9%) Computer – 135 (90%) Either – 2	

Table 2 – Learner Characteristic Summary Data

being an academic institution where a basic language of English proficiency is required.

The academic environment also explains the relatively even distribution of varying levels of academic achievement up to and including doctoral degrees. The majority of study participants had some prior chemical safety training with 25% of classroom and 23% of computer participants having no previous chemical safety training.

Similarly, in terms of experience with working with chemicals, 28% of the classroom and 30% of the computer participants reported no previous experience. Ninety-seven percent (97%) of classroom and 80% of computer participants reported being very or

somewhat satisfied with the training experience. In terms of delivery method preference, 57% of the classroom participants said the classroom method was preferred while 90% of the computer participants said the computer method was preferred.

An analysis of variance (ANOVA) model was used to evaluate differences in learning as measured by exam score (Delta 1) that may be influenced by the selected characteristic categories. ANOVA evaluates the observed variance in Delta 1 values and partitions it into attributable components (Hinkle, et al., 2003). As mentioned earlier, some categories had small numbers, so a minimum of 10 data points was chosen as a cut-off point so as to provide statistical validity to the analysis. In the statistical model tested, Delta 1 was the dependent variable with the various characteristics and classroom versus computer being independent variables. Given the previous criteria, all possible ANOVA models were tested and none were found to be significant at a $p = 0.05$ level. The practical conclusion from this data is that learner characteristics had no impact on learning as measured by exam score (Delta 1). The implications of this will be discussed in the Summary and Conclusions sections.

Evaluate levels of retention of chemical safety information after 1 year by trainees receiving computer-based training versus classroom instruction.

For the second phase of the study evaluating retention, a total of 56 individuals taking classroom training and 72 individuals taking computer training agreed to participate. An identical statistical set of analyses was done to evaluate the issue of retention of chemical safety information after 1 year. To assess the differences in retention between the two

populations as a whole, the mean difference between first post-course Learning Assessment Tool score and the second Learning Assessment Tool administered one year later (as measured by the increase or decrease in number of questions correct out of 16) was calculated (Delta 2). A t-test analysis was conducted comparing the two population means for Delta 2 and is shown Table 3. The -1.40 result indicates that the difference between the two decreases is not significant. The practical conclusion from this data is that training participants lost about the same amount of knowledge after 1 year, regardless of how the training was delivered. The implications of this will be discussed in the Summary and Conclusions section.

As was done with learning (Delta 1), an ANOVA model was used to evaluate differences in Delta 2 that may be influenced by the selected characteristic categories.

Delivery Method	Mean (95% Confidence Interval)	Standard Deviation	T-statistic
Classroom (n = 56)	-1.06 (-1.81,-0.31)	2.86	-1.40 (df=59,p=0.16)
Computer (n = 72)	-0.17 (-0.73, 0.39)	2.43	

Table 3 – T-test Analysis of Average Decrease in Exam Score
(Delta 2) as Measured by Number of Questions Correct
(Difference in Post 1 and Post-Test Scores)

Categories with a minimum of 10 data points were analyzed with Delta 2 being the dependent variable and the various characteristics and classroom versus computer being independent variables. Given the previous criteria, all possible ANOVA models were tested and none were found to be significant at a $p = 0.05$ level. Similar to learning, the practical conclusion from this data is that learner characteristics had no impact on amount of retention as measured by exam score (Delta 2). The implications of this will be discussed in the Summary and Conclusions section.

Summary & Conclusions

The safety professional must consider the previous results in their totality in order to assess any implications for training and course improvements (Step 6 in Figure 1.). The summary statistics on learner characteristics along with the T-test and ANOVA analyses can be used to shed light on potential implications for future training endeavors.

Learning

The T-test results for differences in learning as measured by exam score (Delta 1) show that participants taking chemical safety training in the classroom or on the computer learn the same amount of information. It should be noted that the two versions of the training course were identical and considered to be high quality. This would support an overall conclusion that both delivery methods provide an equivalent learning experience for the participant. The ramifications of this finding are potentially significant to ISU (or any organization). One potential cost-savings measure is to reduce the amount of staff time spent in the classroom. If the safety professional wanted to reduce

time spent conducting safety training, confirmation of an equivalent learning experience being provided by the computer-based version of a course would support a reduction in or even elimination of the number of classroom-based offerings. The safety professional could then devote time to other aspects of the overall safety program.

Retention

The T-test results for differences in retention as measured by exam score (Delta 2) show that there is comparable loss of chemical safety information over the course of a year and that there is no significant difference based on delivery method used. These results need to be considered within a certain context. Participants taking this type of training would be expected to use the knowledge as a part of day-to-day activities and thus retain a higher level of knowledge. Conversely, participants taking cardiopulmonary resuscitation (CPR) classes, for example, don't typically use the knowledge learned on a regular basis, and thus may be more in need of refresher training. As a result, this finding would be helpful when evaluating issues related to the administration of refresher training. If it has been shown that very little programmatic knowledge is lost over the course of one year, a prescriptive requirement for annual refresher training may be, in fact, a waste of human resources including time spent by the safety professional teaching and training participants sitting through a class (either in the classroom or in front of the computer). If the annual refresher training is mandated by law, an alternative means of showing competency could be devised. One option is demonstrating knowledge by successful completion of a "challenge exam". A potential format would be to post the exam on a website that could be accessed by training participants. The exam would be

administered, scored and could provide immediate feedback on results to the participant.

If a passing score was achieved, a training certificate would be generated and there would be no need to take a refresher class. If the participant failed to achieve the minimum score, directions on how to complete the refresher training course would be given.

Again, applying the methodologies used in this study to confirm retention in other courses could result in additional organizational savings.

Learner Characteristics

ANOVA analyses were done to determine if learner characteristics resulted in any differences in learning and retention. No characteristics had a significant effect on either of these defined dependent variables. However, the methods used to collect key characteristic data of the participant should be considered a part of an overall evaluation of effectiveness. Although there were no significant characteristics identified that impacted learning or retention in this study, the importance of evaluating the learner can't be dismissed. For example, if language proficiency is found to be correlated negatively with test performance, the safety professional must investigate why this is occurring and determine what aspect of the training needs to be modified (e.g. course content, format of assessment question, etc.). Of course, this would have implications for both delivery methods.

While the previous information related to learning and retention is noteworthy, the findings and conclusions must be interpreted in the larger context of participant "success" in the course. As noted, the basis of this study was a low-engagement, exam-based

course. Successful completion of training is measured by exam score. The pre-defined pass rate for the chosen chemical safety course was 70% correct. An analysis was done of each population relative to how many participants passed the course at this level. Interestingly, 70 of 92 (76%) classroom participants achieved a score of 70% or greater on the pre-test; for the computer participants, 110 of 151 (73%) achieved 70% or greater on the pre-test. These numbers are reflective of all participants, some of which have significant experience working with chemicals or have had prior chemical safety training. A similar analysis of study participants that reported no prior experience working with chemicals and no previous chemical safety training shows that 8 of 17 (47%) classroom participants and 15 of 22 (68%) computer participants achieved a passing score on the pre-test. Clearly, this information raises questions related to 1) exam difficulty and 2) pre-determined passing scores.

Assessment Technique

The issues of exam and question difficulty mentioned earlier are important. With the prevalence of low-engagement, exam-based safety training being conducted today, the components of the assessment technique may be a factor in deeming a person “qualified” (as defined by successful completion of an exam) or not. An exam that is too easy may allow participants to pass that don’t truly have a sufficient amount of knowledge. Conversely, an exam that is too difficult may result in an unfair assessment of a participant’s knowledge. The net result of this would involve more utilization of resources (i.e. the participant has to take the course over; the instructor may need to

spend additional time reviewing the material with the participant). Both situations beckon the safety professional to critically evaluate assessment technique.

Recommendations for Future Research

Paradise (2007) reported that the total cost of employee training in the United States exceeds \$126 billion annually. Clearly, the financial stakes involved with implementing a training program are significant and demand that this be a key focus area for every organization. The results of this study would also allow cost savings from the standpoint of both the trainer and the participant. As most organizations are continually evaluating ways to reduce costs, the data generated by the mechanisms discussed in this study will allow the training program to be a part of an overall discussion about cost-savings. The data would also show that cost-savings are occurring without sacrificing “quality” in terms of providing equivalent learning experiences. Assuming that the methodologies used in this study could be applied to other safety training courses, there is potential for this trend to continue and result in further savings to the organization.

While costs savings are certainly important, additional studies are necessary to shed further light on issues related to the effectiveness of safety training. The call for more research by NIOSH was quoted earlier and was based on a literature reviewed conducted in 2010. In order to further advance the state of knowledge on the connection between training and injury/illness reduction, more safety professionals must get involved in examining and reporting issues related to learning, retention, characteristic variables and assessment techniques. It should be clear that the current amount of understanding on

this topic, as evidenced by a limited body of scientific literature to date, is still in its infancy.

In conclusion, the methodologies presented in this paper should be considered for use by safety professionals in other work settings. The value of evaluating safety training effectiveness cannot be overstated. The secondary benefit of potential cost reductions have been discussed and may be significant. Only by taking a critical look at how well training is working and using some of the tools discussed in this paper, will the safety professional and organizational leadership have assurance that employees are being provided quality, cost-effective as a part of an overall workplace safety program.

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CHAPTER 4

CHEMICAL SAFETY TRAINING:

THE IMPORTANCE OF CONSIDERING THE ASSESSMENT TECHNIQUE

A Paper to be Submitted to Chemical Health and Safety

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Introduction & Background

Safety training is conducted using a variety of delivery methods. In addition to traditional classroom offerings, safety professionals have been utilizing new technologies, such as computer-based training, at an increasing rate since the 1980s. A study conducted by the International Data Corporation (Overheul, 2002) projected that 80% of safety training would be conducted via a computer by 2003! Accordingly, studies on the effectiveness of training began to emerge in the scientific literature that examined differences in learning between the two methods (Hasselbring, 1986; Kulik & Kulik, 1991; Stephenson, 1991; Bowan, et al., 1995; Williams & Zahed, 1996; Lawson, 1999; Coppola & Myre, 2002; Robson, 2010).

Regardless of the delivery method for safety training, learning outcomes must first be defined. Once defined, effectiveness of the training can be evaluated relative to the success in achieving learning outcomes. In a recent literature review funded by the

National Institute for Occupational Safety and Health (NIOSH), four categories of learning outcomes were identified: knowledge (typically shown via a written exam covering a particular policy, procedure or hazard), attitudes & beliefs (including perception of risk), behaviors (meaning worker actions that could result in exposure to hazards) and health (referring to early detection of illnesses/injuries) (Robson et al., 2010). Of the four outcomes, the most common in safety training is showing knowledge via a written exam (Burke, 2006). At Iowa State University, the majority of current safety training offerings have a written exam component (R. Book, personal communication, December 6, 2010).

The safety professional has numerous issues to consider when composing a written exam. What are the appropriate questions to ask? Are questions clear on what they are asking? Did the training course cover the topic in sufficient detail to allow the participant to answer the question correctly? At this point, the safety professional is faced with a dilemma. Most safety professionals are not well versed on principles related to question design and testing. Weidner (2000) stated that while safety regulations with training requirements are based on known scientific principles related to hazards, they often lack the underpinnings of the principles of adult learning and assessment. This becomes increasingly important when considering the measure of success in exam-based safety training: achievement of a minimum passing score (percentage) on a post-course test. In general, a 70% score is widely accepted as an indicator of “moderate” knowledge, 80% of “moderately higher” knowledge, and so forth (Angoff, 1984). However, the safety professional must wrestle with issues related to question design and exam difficulty in

order to establish a meaningful passing level. This is especially important given the prevalence of exam-based safety training.

Research Objectives

A research study was undertaken to further explore issues related to question design and exam difficulty. The study focused on a chemical safety training course offered at Iowa State University that is an example of exam-based safety training. The course is offered in both classroom and computer-based formats and is considered the backbone of the University's chemical safety program. The course provides basic chemical safety programmatic information to the learner and provides a "roadmap" by which a research group-specific safety program can be developed and implemented. Course topics covered include: regulations, terminology, roles and responsibilities, exposure controls and prevention, recordkeeping, exposure monitoring, Material Safety Data Sheets (MSDS), emergency preparedness, Personal Protective Equipment (PPE) and lab maintenance and inspection.

The first topic evaluated was question difficulty. A specific, associated research question was as follows:

Evaluate the potential impact of question difficulty as a part of an assessment technique that measures learning.

Related to question difficulty, the larger issue of overall exam difficulty was also explored. The specific, associated research question was as follows:

Evaluate the potential impact of exam difficulty and sequence of exam administration as a part of an assessment technique that measures learning.

The results of the study were used to identify lessons learned that could be applied to programmatic and course improvements. An additional purpose was to demonstrate simple techniques that can be used or adapted for use by other safety professionals when evaluating the issue of question and exam difficulty relative to an exam-based safety training course.

Materials & Methods

The data collection mechanism used was a Learning Assessment Tool (LAT). The LAT consisted of 16 questions, each testing knowledge of a specific topical area. Three versions of the LAT were developed in consultation with an “expert panel” composed of chemical safety specialists on campus. Question consistency across the three versions of the LAT was tested using a Wilk’s’ Lambda test statistic. In other words, if the three questions were clearly written and the participant had salient knowledge of the topic, all questions should be answered correctly. Conversely, in a situation where the participant did not have knowledge of the concept, all three questions would be answered incorrectly. The LAT was administered prior to and after training. In classroom sessions, the pre-test and post tests were handed out to participants. In computer-based sessions, the pre and post-tests were presented to the participant automatically on the computer. In each case, the version (1, 2 or 3) was randomly selected either by the

instructor or computer program. Upon completion of the course, a second and different version of the LAT was administered. Upon completion, each LAT was scored for number of questions correct. In addition, the number of individuals getting a particular question correct (or not) was also collated for each question on the three versions of the LAT.

Results & Discussion

Question set analysis via the Wilk's' Lambda test statistic revealed 3 of the 16 topical areas that had one of three questions that were not consistently answered correctly relative to the other two. The three discrepancies were in the areas of training records, regulations and laboratory audits. A review of the individual questions did not reveal any apparent issues with clarity (as described before) that would warrant restructuring of the question. This information was used to review the content of both versions (computer and classroom) to ensure that it was being delivered clearly prior to the commencement of the study.

A common method for evaluating question difficulty is by evaluating the "difficulty factor" (DF) (Knauper et al., 1997). DF is calculated by taking the number of individuals answering the question correctly divided by the total number of participants answering the question. In general, a calculated DF of >0.7 is considered to be an "easy question"; a DF of <0.3 is generally regarded as a difficult question. If the purpose of a test is to discriminate between different levels of achievement, items with difficulty values

between 0.3 and 0.7 are most effective. The optimal level should be 0.5

(http://www.asu.edu/uts/pdf/Guide_stat_analy_exam_scores.pdf).

For the purpose of assessing exam question difficulty, a difficulty factor (DF) was calculated for each question on each LAT when taken as a pre-test. The pre-test was chosen so as to minimize any learning effect caused by participation in the training.

Results are shown in Table 1.

TOPICAL AREA	LAT 1	LAT 2	LAT 3
Regulations	<i>1.0</i>	.23	.37
Laboratory Practices	.58	.46	<i>1.0</i>
Emergencies	.50	.38	.50
Exposure Control	.92	.15	.50
Training	.75	.38	.75
Material Safety Data Sheet	.25	.92	<i>1.0</i>
Personal Protective Equipment	.92	<i>1.0</i>	.75
Inspections	<i>1.0</i>	.92	.13
Postings	.58	.92	.75
Lab Procedures	.92	.15	.75
Labels	.83	.58	.63
Transportation	<i>1.0</i>	.92	.75
Behaviors	<i>1.0</i>	<i>1.0</i>	.88
Spills	.92	.85	.88
Standard Operating Procedures	.98	<i>1.0</i>	.25
Waste Disposal	.17	<i>1.0</i>	.88

NOTES: LAT = Learning Assessment Tool; values >0.7 are *italicized*; values <0.3 denoted in **bold**

Table 1. Pre-Test Difficulty Factor Data – Participants with No Prior Work Experience or Previous Chemical Safety Training

An analysis of the data for each LAT shows that each version had a majority of questions that had a $DF > 0.7$ (values are italicized). Specifically, LAT Version 1 had 11 of 16, LAT Version 2 had 9 of 16 and LAT Version 3 had 10 of 16 questions with calculated DFs that were greater than 0.7. Conversely, each LAT also has several questions that fit the difficult criteria (<0.3) (denoted in red). Specifically, LAT Version 1 had 2 of 16, LAT Version 2 had 3 of 16, LAT Version 3 had 2 of 16. The data tends to support an overall conclusion that the exams are weighted on the “too easy” side. Given that the data was generated by a group of participants that had no prior work experience with chemicals or any prior chemical safety training further supports that conclusion.

To further evaluate the issue of LAT difficulty, an analysis was done of overall pass rate for each LAT for the same group, participants with no prior work experience with chemicals or any prior chemical safety training. For LAT Version 1 taken as a pre-test, 83% of participants achieved a 70% or greater; the passing rates were 54% for LAT Version 2 and 75% for Version 3. This data suggests that the difficulty of each version might be different (i.e. Version 2 is more difficult than the other two). The implications of question and LAT difficulty will be discussed in the Summary and Conclusions section.

Another variable was explored: order of assessment of the LAT. Inherent in the development of the three versions of the LAT was an assumption that all three were of equal difficulty. Given the previously described methodology, there were several possible combinations of administering the three versions of the LAT as pre and post-

tests. To evaluate the question of whether or not all LAT versions were equivalent in terms of difficulty, all possible combinations of the three versions were evaluated for amount of learning as measured by exam score (defined as Delta 1). An analysis of

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Statistic	Probability > F
Version Group	5	589.387	117.877	28.88	<0.0001
Delivery Method	1	20.392	20.392	5.00	0.026
R-Square	0.397				

NOTES:

Version Group 1 = LAT 1 then LAT 2
 Version Group 2 = LAT 1 then LAT 3
 Version Group 3 = LAT 2 then LAT 1
 Version Group 4 = LAT 2 then LAT 3
 Version Group 5 = LAT 3 then LAT 1
 Version Group 6 = LAT 3 then LAT 2

LEAST SQUARES MEAN:

Version Group 1 = -0.233
 Version Group 2 = 0.265
 Version Group 3 = 3.538
 Version Group 4 = 3.466
 Version Group 5 = 2.182
 Version Group 6 = -0.020

Table 2 – ANOVA for LAT Order

variance (ANOVA) model estimated with Delta 1 defined as the dependent variable and LAT order (Version Group) and computer or classroom (Delivery Method) as the independent variables. Table 2 shows the results.

The *p*-value data shows that both the Version Group and Delivery Method are significant in terms of explaining differences in learning as measured by exam score. The calculated value of R^2 was 0.397 which indicates a strong model (defined as: Learning

(Delta 1) = Version Group + Delivery Method). The least squares mean data points out two interesting trends. As can be seen, study participants taking version 2 as a pre-test and either version 1 or 3 as a post-test showed the greatest increase in learning of all possible combinations. A possible explanation of this result is that participants scored low initially on Version 2 because of increased difficulty. When Version 1 or 3 were taken as the post-test, the amount of measured learning was greater than the other combinations. Conversely, study participants who took either Version 1 or 3 as a pre-test may have scored higher initially because they were easier, and then showed less learning (or even a decrease) due to Version 2, as the post-test, being more difficult. The combination of these two observations suggests that Version 2 is a more difficult LAT than either Version 1 or 3. The implications of this finding are discussed in Summary & Conclusions.

Summary & Conclusions

When considering the previous data, it should be obvious that the topic of assessment technique needs to be given consideration by the safety professional very early in the training development process. The reliability testing conducted during the development of the LAT provided valuable feedback that was a catalyst for a review of training content. An analysis of difficulty factor data, the overall pass rate for each LAT and the influence of exam order, suggested that Version 2 of the LAT was more difficult than the other two. But, at this juncture, another issue must be considered by the safety professional: establishing a passing level. As was shared previously, 70% is a commonly used passing level in safety training. But, how can the safety professional

establish a passing level without consideration of the issues of question and exam difficulty as well as order of administration? In our example, a majority of questions that had a $DF > 0.7$ (LAT Version 1: 11 of 16, LAT Version 2: 9 of 16, LAT Version 3: 10 of 16). Conversely, each LAT also has several questions that fit the difficult criterion (< 0.3) (LAT Version 1: 2 of 16, LAT Version 2: 3 of 16, LAT Version 3: 2 of 16). Without an understanding of composition of the LAT, in terms of the distribution of difficult or easy questions, the impact and value of the safety training is difficult to determine. Management might look at the high rate of safety training completion and falsely conclude that workers, because of participation in safety training, are now “qualified” when, in reality, the assessment technique did not have sufficient rigor. Conversely, the safety professional might look at low pass rates for a given safety course and conclude that some aspect of the course (e.g., content) needs improving when, in reality, the assessment technique used was too difficult.

A similar discussion is necessary related to exam difficulty and order of administration. As was shown in this study, both exam difficulty and order of administration played a key role in the measured amount of learning. A false assumption was made that each exam had the same amount of difficulty when, in fact, one version was more difficult than the other two. A training participant who took the more difficult version of the exam as a pre-test and then showed a significant gain in knowledge on a post-test might lead the safety professional to conclude that the training intervention was highly effective. Conversely, if the participant took the more difficult version of the

exam as the post-test, the false conclusion would be that the training intervention was not very effective (i.e., the participant didn't learn much).

It should be obvious that data related to question and exam difficulty are necessary in order for the safety professional to evaluate safety training course effectiveness. Data generated in this study indicate a need to further evaluate the composition of LAT version 2. Any changes made in individual questions would necessitate the need to re-evaluate issues related to pass rate, etc. If the safety professional can show equivalent difficulty with each version of the LAT, then improvements in the assessment technique can be made. For example, raising the passing rate to 80% or higher might be evaluated as an option. But, what additional issues will that present in terms of ensuring the adequacy of content, length of course and other variables related to delivery methods? Will the safety professional be spending more time with participants who don't achieve a passing grade outside of class and therefore be devoting more of his/her limited time to supporting the overall training program?

Developing an effective safety training program is challenging in any work environment. Clearly, there are many complexities associated with evaluating safety training effectiveness. Sugure & Rivera (2005) reported that only about 50% of companies measure learning outcomes from training, and less 25% make any attempt to assess potential programmatic improvements resulting from training! Today, the pre-dominant type of safety training includes administration of a written exam and the achievement of a minimal score as a measure of success. To properly evaluate this type

of assessment technique, it is imperative that the safety professional have the necessary data collection mechanisms in place. The evaluation of this data and the resulting enhancements of the training will be an on-going and iterative process.

This study has demonstrated the usefulness of several straightforward analytical techniques that can be used to assess issues related to both question and exam difficulty. It should be noted that the issue of exam difficulty was done within a specific chemical safety course. The results presented and discussed in this study cannot be used to predict potential outcomes of evaluations of other courses. The only way to truly shed light on issues related to the value of the assessment technique being used is to implement a process by which course and exam-specific data can be collected and analyzed. The need to include this important step in the developmental process is directly related to the significance of the subject matter of the training course and the intended learning outcomes. Verifying the accuracy of exam-based safety training associated with high hazard occupations is absolutely critical. In this situation, the knowledge being gained in training is the basis of an employee making perhaps a life or death decision. This was vividly brought to the general public's attention after the terrorist attacks of September 11, 2001, relative to the actions of emergency responders and their lack of training (Rudman, 2003). In this context, there must be a clear indication of learning that results from the training experience and not be influenced by nuances (e.g., exam difficulty and exam order) associated with the assessment technique.

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CHAPTER 5: GENERAL CONCLUSIONS

The literature review presented in Chapter 1 provided a historical perspective on the general issue of training and, more specifically, workplace safety training. Literature references to learning theory date back to the 1960s (Dale, 1969). The establishment of OSHA in 1970 and the associated promulgation of workplace safety regulations led to the agency publishing guidance information on how to develop safety training (OSHA, 1998). Beginning in the 1980s, the issue of safety training effectiveness began to be investigated and reported (e.g., Vojtecky & Schmitz, 1986). The concurrent and increasing availability of computer technologies fueled further studies on effectiveness of training. Most of the reported literature focused on the issue of differences in learning between traditional classroom and computer-based methods (e.g., Williams & Zahed, 1986); a smaller body of work looked at the issue of retention (e.g., Lawson, 1999). All the while, in the arena of adult learning theory, research continued as well. Dale's "Cone of Learning" was both celebrated (e.g., Bligh, 1998) and panned (e.g., Coffey and Gibbs, 2002). University faculty in academic settings like ISU introduced future teachers to Bloom's Taxonomy which described learning as a sequential process that first begins with the acquisition of knowledge following by understanding, applying, analyzing, evaluating and creating (Clark, 2004). The merging of these two areas of interest, safety training effectiveness and adult learning theory, began to be discussed more in the literature. Burke (2006) defined levels of engagement and conducted an extensive meta-analysis on the reported literature that discussed safety training effectiveness.

The research study generated data and conclusions in three major areas. Each area was discussed in detail in Chapters 2, 3 and 4. A recap is as follows:

Proposed Model

The case study described in Chapter 2 dealt with evaluating the usefulness of the proposed six-step model. The model was not innovative, but rather a logical synthesis of approaches proposed by OSHA, NIOSH and ANSI. Many conclusions were presented. In the area of establishing goals and objectives, it was recognized that not all safety professionals will have access to an “expert panel” of discipline specialists. The need to reach out to other peer groups was suggested. The collaborative, peer-to-peer process for identifying goals and objectives for training and identifying content is essential. The different experiences and perspectives brought to the table by each safety professional also served as the forum for determining “success”. As has been shown in this study, establishing a minimal passing level and evaluating the assessment technique are intertwined. Failure to adequately evaluate this as a part of an identified goal or objective (i.e. have all participants “pass” by achieving a 70% on the exam) might falsely give the safety professional and the organization confidence that workers are “qualified” as a result of taking safety training. The importance of identifying clear and measurable goals/objectives for training lays the foundation for an effective program and must be done.

In the area of evaluating the learner, there is no doubt that many safety professionals will feel ill-equipped due to lack of experience, education or both. Yet, in this project, a

fairly simple method was devised and implemented. A simple understanding of the characteristics of the learners is an excellent first step and integral part of devising an effective training delivery method. While the learner characteristics used in this study were gleaned from pertinent literature references, the safety professional is free to define what type of characteristic survey will be useful for a given work environment. The process of defining, collecting and analyzing pertinent characteristic data will help the safety professional to better understand the learner and adjust the safety training accordingly. Again, the ultimate benefactor is the training participant.

Identifying the best delivery method will continue to be a challenge for the safety professional. At ISU, there is a general trend towards moving more of the safety training curriculum to a computer-based format. The need for this is being driven primarily by shrinking resources (e.g., staff time devoted to teaching). Safety departments are being asked to perform an increasing number of services, including training, with fewer staff. This obvious conflict drives the need for efficiency. Emerging technologies offer much promise, but cannot be considered without a concurrent discussion about and evaluation of efficacy.

The evaluation of effectiveness (Step 5) component was absolutely critical and allowed for a more focused study of several key issues that resulted in the data presented in Chapters 3 & 4. Numerous examples of applying lessons learned (Step 6), were given and the safety professional was encouraged to use or adapt the processes of the study to initiate studies of effectiveness.

In conclusion, the proposed model provided a significant amount of useful information and was deemed an effective tool for use by other safety professionals as is or can be adapted to fit certain circumstances.

Learning & Retention

The research questions defined in Chapter 3 dealt with issues of learning, retention and differences in characteristics of the learner. It is easy to understand how methods for evaluating the effectiveness of the training might be minimal or, in some cases, non-existent. The lack of knowledge and experience in program evaluation and assessment, as detailed by Vojtecky & Schmitz (1986), was cited as a key factor.

What can the safety professional learn from the information reported in Chapter 3? The prevalence of low-engagement, exam-based safety training and the use of computer technology will continue to demand an evaluation of learning and retention and factors that might influence both processes. As was stated, being able to show equivalent learning experiences between two methodologies (for an equivalent, high-quality training course) can be seen as a positive, in terms of supporting a decision, for example, to reduce the number of classroom sessions offered per year. In fact, since the conclusion of the study, the chemical safety course used to collect data is now offered exclusively on the computer. A thorough evaluation of differences in learner characteristics concluded that there were no significant issues related to potential influences that might impact the measured amount of learning. The data collection techniques used to address these issues

and the statistical methods employed to provide data that supports decision making were straightforward. In the area of retention, it was shown that minimal loss of chemical safety knowledge is lost over the course of a year. This is encouraging and can have significant programmatic implications. Allowing for alternative means of verifying on-going competency via mechanisms like a challenge exam were discussed and will conceivably save resources. However, programmatic changes like this can only be made with supporting data. The mechanisms used in this study allowing for collection and analysis of data of retention were also very straightforward. As more courses are moved to a computer-based format and as new technologies are introduced and tested as delivery methods for safety training, the safety professional must not forget to simultaneously engage in an evaluation of effectiveness.

Assessment Technique

Chapter 4 delved into several issues related to assessment technique. These issues emerged as a result of the focus of the study being on a low-engagement, exam-based safety training course.

The reliability testing of the LAT questions provided valuable feedback that initiated a quality assurance review (i.e., make sure the content is being covered in the course) prior to the launch of the course. The concept of difficulty factor for each exam question was introduced and applied to the data collection mechanisms used in the study. For a pre and post-test format (or question bank format), it was stated that it is critical that some evaluation of exam difficulty also be conducted. Also discussed in Chapter 4 was

the challenge of establishing a “passing level”. It was stated that it is impossible to truly define this level without first delving into the issues of question and exam difficulty. Finally, the issue of order of exam administration was explored and discussed within the context of potential impact on the measured amount of learning.

In conclusion, Chapter 4 points out the necessity of collecting data on the components of the exam mentioned previously and that this iterative process (collect data, analyze data, make improvements) is essential to ensuring the quality of the training experience that utilizes a low-engagement/exam-based assessment technique.

Overall Recommendations

The following quote from the 2010 NIOSH report (Robson, 2010, page 1) on evaluating training effectiveness was cited in each of the preceding chapters and is worth repeating here:

Research on the effectiveness of Occupational Health and Safety (OHS) training is needed to: 1) identify major variables that influence the learning process and 2) optimize the allocation of resources for training interventions. In research on training, it is often difficult to arrive at definitive conclusions about effectiveness. Typically, many workplace characteristics contribute to real-world effects of training. Designing studies that validate the unique contribution of individual factors, such as specific training program features, are often infeasible. Traditional narrative literature reviews of training are often speculative about specific factors that enhance the relative effectiveness of OHS training interventions in reducing occupational injuries, illnesses and deaths.

As one ponders the historical evolution of safety training and effectiveness, a reasonable conclusion is that the state of knowledge is still in its infancy. NIOSH is clearly stating that it is a necessity to consider human factors or characteristics of the learner when evaluating effectiveness. Also, NIOSH clearly recognizes the important connection between training effectiveness and large issues such as the amount of organizational resources that go into training.

If the previous “state of affairs” is agreed upon, what role does the day-to-day safety practitioner play in advancing the current level of understanding of safety training effectiveness? The research study previously described was purposely designed in recognition of the most common combination of training course characteristics: low engagement, exam-based, computer and classroom delivery methods. Each chapter describes a major area of focus that provided valuable information addressing concerns raised by NIOSH. Many forward thinking employers recognize the connection between quality and safety. Put another way, most world-class organizations have world-class safety programs. Presidents, chief executive officers and boards of directors recognize the value of high-performing human resources. These individuals realize that it doesn’t make any sense to have an employee come to work healthy and then leave sick or injured. Poor training can pre-dispose an employee to accidents ranging from minor to severe. Put another way, potential outcomes of poor training can be a serious injury or even a fatality. Forward thinking employers look at effective training not just as a regulatory requirement but rather as the right thing to do. The sheer economics of effective and efficient safety training have been discussed and are also recognized by

forward thinking organizations. The importance of proper development and evaluation of each safety training course cannot be overstated. In accident investigations, lack of or insufficient training is often cited as a causal factor. Most successful organizations “get” the inter-relationship between training, quality and business performance.

The results discussed in each chapter provide many examples of applying lessons learned information to both a specific safety training course and the overall training program. At this point, the NIOSH publication referenced earlier needs to be re-considered (Robson, 2010, page 77):

Investment in training research: As illustrated by this review, there were relatively few high quality well-controlled studies of training effectiveness. In part this is due to the fact that controlled trials of training factors and impact are difficult and time-consuming to conduct. The small number of studies included in this review may also be due to the lack of targeted investment by governments for training research, and the failure of researchers to submit grant applications, or the inability of grant review panels to effectively assess grant applications for training research. Given the positive impact of training and relatively large amounts of funds invested by corporations and organizations, there is a need for more increased high quality training effectiveness research.

While the previous statement may be interpreted as being directed at governmental agencies and academia, there is a role for the day-to-day safety practitioner to play in the advancement of the state of knowledge. Accordingly, this research endeavor was the result of recognition of 1) the importance of putting serious thought into the design, delivery and evaluation of safety training, 2) the importance of presenting and testing potential methods for evaluating the effectiveness of safety training and publishing the results, and 3) the ability of the day-to-day safety practitioner to actually work through

such a process. And, this was done in the context of currently used delivery method and assessment technique that will undoubtedly be around for a long time.

As stated at the very beginning of this study, employee training will continue to be a critical part of every organization. Computers have been discussed extensively, but even newer technologies (e.g. Podcasts, Twitter) are now at the disposal of the safety professional as potential delivery methods. These new technologies will have great potential to even more efficiently meet the training needs of the organization and positively impact the “bottom line”. It is imperative that lessons learned information on studies of training effectiveness, like those produced in this study, are submitted for publication in refereed safety journals. Safety professionals should share findings in the form of poster and platform session requests to national conferences. Occupational safety and health curriculums at universities should include courses on adult learning theory and program evaluation and assessment as core requirements. Only with the continued addition to the base of knowledge on training effectiveness will the safety profession come to a clearer understanding of what is best in terms of training methods that have the greatest impact on reducing or, better yet, eliminating work place accidents and injuries.

Post-Study Reflection

The lessons learned from the study conducted were significant and offered many suggestions for course and programmatic improvements. In addition, there were several

lessons learned related to study design and scope that would make future studies even more instructive.

In the area of study design, several enhancements of the data collection and analysis methodologies could be made. Related to the reliability testing of the Learning Assessment Tool, exam questions were reviewed for clarity by the focus group and word and question change suggestions were incorporated into the final question set. The validation process would have been strengthened by a second review by a different focus group, perhaps of different ethnicities than the original group. This second review would result in additional clarity. A second improvement is related to the actual data collection mechanisms for the LATs and the characteristic survey. Exam and survey responses were solicited by completion of a hard copy LAT and characteristic survey. It is possible that the data would have been more easily managed (manipulated) if a bubble sheet format had been used. This format is commonly used on college campuses and allows the use of certain statistical services provided by the testing and evaluation department. A third improvement related to study design would be to use the same version of the LAT for the pre and post-exam collection of data. Using this strategy would allow an even clearer assessment of true learning as a result of the training intervention and would eliminate the variable of exam difficulty and order of administration.

In the area of further validation of the approach embodied in the proposed model, it would be very interesting to use the methodologies described in this study in a completely different work environment. The academic environment is certainly unique

in terms of nuances associated with evaluating the effectiveness of safety training.

However, the validity of the approach used in this study could be strengthened by testing in a variety of different settings. For example, what would be learned from applying the methods to a study of safety training effectiveness in an industrial production facility? Would the model be further validated or would the results suggest that the model is no good or perhaps should be modified? Since safety training is potentially a part of almost every workplace, additional case studies would add knowledge to the overall understanding of safety training effectiveness.

Another issue that could have been explored is that of differences in learning styles amongst training participants. Adaptation of the learner characteristic survey would have allowed collection of data that may have shed light on the issues being examined in this study. For example, would there be any influence on the results observed when comparing participants that self-identified themselves as “visual learners” versus those that identified themselves as “auditory learners”.

It is abundantly clear that only through more study and analysis of training effectiveness will the gap between safety training and injury /illness reduction be understood. As has been stated repeatedly throughout this study, as more data is accumulated, the ultimate benefactor will be the training participant.

APPENDIX A.

Three versions of Learning Assessment Tool (LAT)

**LAB SAFETY: FUNDAMENTAL CONCEPTS
LEARNING ASSESSMENT TOOL (VERSION 1)**

- 1) Which of the following is a requirement of OSHA's Laboratory Standard?
 - a) Information and training for employees working with hazardous chemicals
 - b) Chemical inventories, Material Safety Data Sheet and labeling of container
 - c) Development of standard operating procedures for use of chemicals
 - d) All of the above are requirements of the OSHA Laboratory Standard
- 2) Laboratory employees are responsible for all the following except?
 - a. Attending designated training
 - b. Granting prior approval for use of particularly hazardous substances in the laboratory
 - c. Reviewing chemical processes with lab supervisor
 - d. Labeling, storing and disposing of chemicals properly
- 3) In the event of a medical emergency such as a chemical exposure (for example, skin burn) or an injury that occurs after working hours, a University employee or student should seek medical treatment at:
 - a. Occupational Medicine Center at McFarland Clinic in Ames
 - b. Mary Greeley Medical Center Emergency Room in Ames
 - c. Occupational Medicine located in G11 TASF on campus
 - d. Thielen Student Health Center on campus
- 4) Which of the following is not an acceptable way to reduce your exposures to hazardous chemicals?
 - a. Moving the operation into a chemical hood
 - b. Selecting personal protective equipment matched to the hazards of chemicals being used
 - c. Asking a co-worker to complete the experiment for you
 - d. Using a less hazardous chemical
- 5) Which of the following records can be used to document training completion?
 - a. Certificates issued by the safety office.
 - b. Printout of training history from the Environmental Health & Safety online Learning Center
 - c. Medical records
 - d. Only A and B
- 6) Material Safety Data Sheets (MSDSs) can be obtained from:
 - a) On the internet via a Material Safety Data Sheet (MSDS) web site
 - b) ISU Department of Public Safety
 - c) Environmental Health and Safety (EH&S) MSDS library
 - d) All of the above
 - e) Only A and C
- 7) Which of the following should be performed when you have completed work with hazardous chemicals?
 - a) Decontaminate and disinfect Personal Protective Equipment (PPE) if it will be used again

- b) Store Personal Protective Equipment (PPE) in a clean, dry place away from heat and sunlight
 - c) Wash hands with soap and water
 - d) All of the above
 - e) None of the above
- 8) Laboratory safety inspections are to be conducted annually, at a minimum, at ISU. Pick the best answer from below:
- a) Inspections provide feedback to laboratory personnel on issues such as housekeeping
 - b) Inspections should examine all safety aspects of the lab's operation including training records
 - c) Correct labeling of chemical containers can be verified during an inspection
 - d) All of the above
- 9) The entrance to a laboratory must be posted with what information?
- a) Inventory of chemicals present in the laboratory
 - b) Identification of special hazards present in the lab
 - c) Emergency contact information for the lab supervisor and other responsible people
 - d) All of the above
 - e) Only B and C
- 10) Procedures for ordering chemicals include all of the following except?
- a) Prepare the laboratory for the arrival of the substance (e.g., location, signage, Personal Protective Equipment (PPE)).
 - b) Order the full quantity of chemicals needed at the beginning of the project to reduce ordering and processing time
 - c) Obtain approval from the lab supervisor before ordering
 - d) Only select chemicals for which adequate ventilation or other control measures are available
- 11) Laboratory chemical container labels must include what information?
- a) Identification of contents
 - b) Basic hazard statement such as "flammable" or "irritant"
 - c) A signal word such as "danger" or "warning"
 - d) All of the above
 - e) Only A and C
- 12) Chemicals transported by hand from one location to another must be carried in what?
- a) Shock-resistant carriers, containers or buckets
 - b) Sealed plastic bags
 - c) Inside a cardboard box at minimum
 - d) Paper wrapping
- 13) Which of the following are examples of safe behaviors for laboratory workers?
- a) Do not smell or taste chemicals
 - b) Do not eat or drink in the laboratory
 - c) Do not siphon or pipette liquids by mouth
 - d) All are examples of safe behaviors

- 14) Which of the following equipment and supplies should be kept in the lab for the management of spills and accidents?
- a) Neutralizing agents
 - b) First aid kits
 - c) Absorbents
 - d) All of the above
 - e) Only A and B
- 15) Who develops standard operating procedures (SOPs) for work involving chemical, biological and radiological materials?
- a) Environmental Health and Safety
 - b) Each investigator or laboratory work group
 - c) Laboratory Safety Contact
 - d) University Safety Committee
- 16) Which of the following statements are true regarding generating hazardous waste in the lab?
- a) Waste may be accumulated until graduation.
 - b) Environmental Health & Safety (EH&S) is responsible for properly capping and labeling waste containers.
 - c) All waste generators must receive training.
 - d) Waste can be poured down the drain.

**LAB SAFETY: FUNDAMENTAL CONCEPTS
LEARNING ASSESSMENT TOOL (VERSION 2)**

- 1) The OSHA Laboratory Safety Standard requires that lab employees who work with hazardous chemicals:
 - a) Write experiment-specific standard operating procedures
 - b) Attain prior approval when planning to use particularly hazardous materials
 - c) Autoclave potentially infectious biological materials
 - d) All of the above
 - e) Only A and B

- 2) Laboratory supervisors and _____ are responsible for working together to adapt general laboratory safety policies and procedures to specific laboratory operations.
 - a. University Departments
 - b. Environmental Health & Safety
 - c. Employees
 - d. Occupational Medicine staff

- 3) An ISU student not employed by the University who is exposed or injured in the classroom or laboratory should seek medical treatment at:
 - a. Occupational HealthWorks at McFarland Clinic in Ames
 - b. Mary Greeley Medical Center Emergency Room
 - c. Occupational Medicine located in G11, TASF on campus
 - d. Thielen Student Health Center

- 4) Which of the following is the best way to minimize exposure to a particular chemical?
 - a. Move the operation into a chemical hood
 - b. Use the smallest amount of the chemical necessary
 - c. Eliminate the use of that chemical via substitution of a lesser toxic chemical
 - d. Use appropriate personal protective equipment

- 5) Which of the following records can be used to document training completion?
 - a. Hazard Inventory form
 - b. Laboratory Safety Inspection form
 - c. Laboratory Safety Training Summary
 - d. All of the above
 - e. None of the above

- 6) Material Safety Data Sheets can be obtained from:
 - a) Environmental Health & Safety (EH&S) website
 - b) Chemical manufacturer
 - c) Occupational Medicine
 - d) Only A & B
 - e) None of the above

- 7) When wearing Personal Protective Equipment (PPE), you are responsible for which of the following?
 - a) Learning how to wear and adjust Personal Protective Equipment (PPE)
 - b) Care and maintenance of Personal Protective Equipment (PPE)
 - c) Making sure to wear something, regardless of the types of Personal Protective Equipment (PPE) available in the lab
 - d) Only A and B

- 8) Laboratory safety inspections can provide a variety of useful information to laboratory supervisory personnel and workers. All of the following are true regarding laboratory inspections except:
- a) Conducting a laboratory inspection is a good idea but not required by the ISU Laboratory Safety Manual.
 - b) Laboratory inspections can be used to confirm that all Material Safety Data Sheets (MSDSs) are current.
 - c) Chemical labeling should be checked during a laboratory inspection.
 - d) Deficiencies found during a laboratory inspection should be checked later to assure that the issue has been corrected.
- 9) The entrance to a laboratory must be posted with what information?
- a) A list of the employees authorized to work in the laboratory
 - b) Emergency contact information for the lab supervisor and other responsible people
 - c) Inventory of chemicals present in the laboratory
 - d) Working hours of the laboratory
- 10) Procedures for ordering chemicals include which of the following?
- a) Order in bulk whenever possible to reduce unit cost
 - b) Order all chemicals through Chemistry Stores located in 1401 Gilman Hall
 - c) Prepare the laboratory for the arrival of the substance (e.g., location, signage, Personal Protective Equipment (PPE)) within one month of receipt
 - d) None of the above are correct
- 11) Which of the following pieces of information is not required on container labels for chemicals created in the laboratory and stored in a secondary container (squeeze bottle, flask, beaker, ampule, vial)?
- a) Basic hazard statement such as “flammable” or “irritant”
 - b) Identification of contents
 - c) Quantity in grams or liters
 - d) A signal word such as “danger” or “warning”
- 12) Chemicals may be transported from one location to another using any of the following procedures except?
- a) Shock-resistant carriers, containers or buckets
 - b) Stable cart with large wheels
 - c) On freight-only elevators whenever possible
 - d) Heavy cardboard containers
- 13) Which of the following is an example of an unsafe behavior in the laboratory?
- a) Wearing appropriate Personal Protective Equipment (PPE)
 - b) Following established standard operating procedures
 - c) Rubbing or scratching face, eyes, nose or mouth with contaminated hands
 - d) Keep all work areas clean and uncluttered and aisles clear
- 14) Regarding minor chemical spills, which of the following is true?
- a) Call 911 to report the spill.
 - b) Call Environmental Health & Safety (EH&S), spill clean up is their responsibility.
 - c) Wear appropriate Personal Protective Equipment (PPE) during clean up.
 - d) Leave lab until chemical evaporates.

- 15) Which of the following should be included in a standard operating procedure (SOP):
- a) Hazard control measures including personal protective equipment (PPE)
 - b) Applicable health and safety information
 - c) Decontamination procedures including waste disposal
 - d) All of the above
- 16) It is the responsibility of each person generating hazardous chemical waste to:
- a) Keep wastes in the appropriate location (Satellite Accumulation Area)
 - b) Pour only small amounts of hazardous waste down the drain.
 - c) Label all waste containers after they are full.
 - d) Keep waste containers open so liquids slowly evaporate.

**LAB SAFETY: FUNDAMENTAL CONCEPTS
LEARNING ASSESSMENT TOOL (VERSION 3)**

- 1) The OSHA Laboratory Safety Standard applies to:
 - a) Use of cleaning supplies by custodians (cleaning personnel)
 - b) Laboratory use of hazardous chemicals
 - c) Lubricants used for cutting metal in a machine shop
 - d) All of the above
- 2) Laboratory employees are responsible for which of the following?
 - a. Be aware of laboratory hazards.
 - b. Follow all Standard Operating Procedures (SOPs)
 - c. Report hazardous or unsafe conditions.
 - d. Employees are responsible for all of the above
- 3) ISU employees that are enrolled in the Occupational Medicine Program at ISU are required to complete a baseline medical review at:
 - a. Occupational Medicine Center at McFarland Clinic in Ames
 - b. Mary Greeley Medical Center Emergency Room in Ames
 - c. Occupational Medicine located at G11 TASF on campus
 - d. Thielen Student Health Center on campus
- 4) Chemical users should reduce potential exposures as much as possible. All of the following are ways to achieve this goal except:
 - a. Use a chemical hood whenever possible for work with chemicals
 - b. Work in shifts
 - c. Use appropriate chemical-resistant gloves
 - d. Using a less hazardous chemical
- 5) Which of the following records can be used to document training completion?
 - a) First Report of Injury form
 - b) Printout of training history from the Environmental Health & Safety online Learning Center
 - c) Laboratory Safety Survey form
 - d) Hazard Inventory
- 6) Material Safety Data Sheets can be obtained from:
 - a) ISU Police Department
 - b) Environmental Health & Safety (EH&S) Material Safety Data Sheet (MSDS) library
 - c) Human Resources
 - d) Post Office
 - e) All of the above
- 7) Personal Protective Equipment (PPE) should be selected based on all of the following except?
 - a) Information from selection guides available through the Environmental Health & Safety (EH&S) website
 - b) Exposure routes into the body
 - c) Color of available Personal Protective Equipment (PPE)
 - d) Length of time chemical is used
- 8) According to the ISU Laboratory Safety Manual, routine laboratory inspections should be completed by:
 - a) ISU Department of Public Safety
 - b) Environmental Health & Safety

- c) Laboratory supervisors
 - d) Department Chair
- 9) The entrance to a laboratory must be posted with what information?
- a) Recent laboratory audit findings.
 - b) A list of Standard Operating Procedures (SOPs) for current research activities
 - c) A current chemical inventory
 - d) Emergency contact information for the lab supervisor and other responsible parties
- 10) Procedures for ordering chemicals include which of the following?
- a) Estimate amount required by pre-planning procedure
 - b) Obtain hazard information prior to placing an order
 - c) Order the smallest quantity needed to minimize waste generation
 - d) All of the above
 - e) Only B and C
- 11) You synthesize a chemical sample in the laboratory and store it in a beaker. Which of the following pieces of information is required on the beaker or any other type of secondary container (squeeze bottle, flask, beaker, ampule, vial)?
- a) Basic hazard statement such as “flammable” or “irritant”
 - b) Identification of contents
 - c) A signal word such as “danger” or “warning”
 - d) All of the above
- 12) All of the following are acceptable methods for the transport of chemicals from one location to another except?
- a) Stable cart that won't tip and will contain spilled material
 - b) Personal vehicle
 - c) Shock-resistant carrier, container or bucket
 - d) Freight-only elevator
 - e) A and B are both unacceptable methods for transporting chemicals
- 13) Which of the following would be considered unsafe behaviors in areas where chemicals are used or stored?
- a) Leaving potentially hazardous chemical processes unattended
 - b) Using laboratory glassware for personal food or drink items
 - c) Playing practical jokes or pranks on co-workers
 - d) All of the above
- 14) For minor chemical spills in the lab, all of the following are correct except:
- a) If chemical is flammable, turn off ignition and heat sources
 - b) Call Environmental Health & Safety (EH&S), spill clean up is their responsibility
 - c) Attend to any persons who may have been contaminated
 - d) Wear appropriate personal protective equipment during clean up

- 15) Which of the following is true regarding standard operating procedures?
- a) Developed by Environmental Health and Safety (EH&S) and specific to each piece of equipment.
 - b) Developed by the investigator or working group and specific to each experimental task.
 - c) Developed by the University's Safety Committee and specific to each chemical.
 - d) Developed by the ISU Chemical Hygiene Officer and specific to experimental task.
- 16) All of the following statements regarding hazardous chemical waste are true except:
- a) Hazardous chemical waste regulations are published by the Environmental Protection Agency (EPA).
 - b) Containers labels only require the statement "For Safety Office".
 - c) Hazardous chemical waste generators must be trained.
 - d) Hazardous chemical waste must be segregated just like regular chemicals.

APPENDIX B.

Informational Memo Describing the Study

ISU IRB # 1	07-421
EXEMPT DATE:	27 September 2007
Initial By:	jlc

DATE: _____

TO: Chemical Hygiene Personal Protective Equipment Training Participant

FROM: Jim Withers CIH, CSP
Industrial Hygienist
Environment, Safety, Health & Assurance
G40 TASF; 294-4743; withers@ameslab.gov

**SUBJECT: PARTICIPATION IN RESEARCH STUDY ON COMPARISON OF
LEARNING EXPERIENCES AND RETENTION BETWEEN
CLASSROOM AND COMPUTER-BASED CHEMICAL SAFETY
TRAINING AT IOWA STATE UNIVERSITY**

You are being requested to participate in a research study that investigates the issues of learning experiences and retention of chemical safety information. This information is being collected and will be analyzed in order to improve chemical safety training at Iowa State University. Please keep the following in mind as you consider whether or not to participate in the study:

- 1) The data I'm collecting is confidential and will be maintained in a secure location. The information will only be accessible to me and members of my research committee. All information shared will be in aggregated summaries. No individual identifiers will be shared and no data will be shared that can be connected to an individual. At the conclusion of the study all individual identifiers will be destroyed. The conclusions of this study may be submitted for publication and shared with the safety professionals and members of management at ISU as a means of supporting improvements in the chemical safety training program.
- 2) If you agree to participate in this study, you'll first be asked to complete a survey that requests basic demographic information on age, gender, prior chemical safety training, ethnicity and overall satisfaction with our training experience. Estimated time to complete the demographic survey is 1 minute. Approximately 1 year after completing the training, you will be asked to complete a follow up Learning Assessment Tool.
- 3) You may ask questions at any time by calling or e-mailing me.
- 4) There are no foreseeable risks at this time from participating in this study.
- 6) There will be no direct or immediate benefit to you although it is hoped that information gained as a result of this study will benefit future University employees.
- 7) There is no cost or compensation associated with participation in this study.
- 8) Your participation is completely voluntary and you may refuse to participate or skip any of the questions on the Learning Assessment Tool or demographic survey.

Call or e-mail me with any questions or comments. Thanks for your assistance!

APPENDIX C.

Learner Characteristic Survey

DEMOGRAPHIC SURVEY

NAME: _____ UNIVERSITY ID: _____

- | | |
|---|--|
| <p>(1) <u>Age in years:</u> _____</p> | <p>(6) <u>Number of previous chemical safety courses taken:</u></p> |
| <p>(2) <u>Gender:</u></p> <p>Male</p> <p>Female</p> | <p>0</p> <p>1</p> <p>2</p> <p>3 or more</p> |
| <p>(3) <u>Ethnicity:</u></p> <p>White (non-Hispanic)</p> <p>Black (non-Hispanic)</p> <p>Hispanic</p> <p>Native American</p> <p>Asian</p> <p>Other</p> | <p>(7) <u>Number of years working with chemicals on the job (not including laboratory classes):</u></p> <p>0</p> <p>1</p> <p>2</p> <p>3 or more</p> |
| <p>(4) <u>Please mark the statement that best describes your understanding (speaking, reading, writing) of the English language:</u></p> <p>BEGINNER: Able to understand basic English but am still learning.</p> <p>MODERATE: Able to understand English and have simple conversations.</p> <p>PROFICIENT: Able to understand all levels of English and participate in formal conversations.</p> <p>HIGHLY PROFICIENT: Able to understand at a level that is equivalent to a native English speaker.</p> | <p>(8) <u>Overall satisfaction with today's training experience:</u></p> <p>Very satisfied</p> <p>Somewhat satisfied</p> <p>Somewhat dissatisfied</p> <p>Very dissatisfied</p> |
| <p>(5) <u>Highest education level/degree attained:</u></p> <p>High school diploma</p> <p>Some college</p> <p>2-year degree</p> <p>4-year degree</p> <p>Master's</p> <p>Ph.D., Ed.D., etc.</p> | <p>(9) <u>In the future, I would prefer to take chemical safety training:</u></p> <p>On the computer</p> <p>In a classroom</p> |

APPENDIX D.

Institutional Review Board (IRB) Approval Documentation

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office of Research Assurances
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

DATE: October 2, 2007

TO: James H. Withers
G40 TASF

CC: Dr. Steve Freeman
104 I Ed II

FROM: Jan Canny, IRB Administrator
Office of Research Assurances

IRB ID: 07-421

Study Review Date: 27 September 2007

The Institutional Review Board (IRB) Chair has reviewed the project, "Chemical Safety Training via Classroom or Computer-Based (CBT) Formats: Effects on Learning and Retention" (IRB ID 07-421) and has declared the study exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b), Exempt Category (1). A description of this exemption category can be found in the list on the next page. Please note that you must submit all research involving human participants for review by the IRB. Only the IRB may make the determination of exemption, even if you conduct a study in the future that is exactly like this study.

The IRB determination of exemption means that this project does not need to meet the requirements from the Department of Health and Human Service (DHHS) regulations for the protection of human subjects, unless required by the IRB. We do, however, urge you to protect the rights of your participants in the same ways that you would if the project was required to follow the regulations. This includes providing relevant information about the research to the participants.

Because your project is exempt, you do not need to submit an application for continuing review. However, you must carry out the research as proposed in the IRB application, including obtaining and documenting (signed) informed consent if you have stated in your application that you will do so or if required by the IRB.

Any modification of this research should be submitted to the IRB on a Continuation and/or Modification form, prior to making any changes, to determine if the project still meets the Federal criteria for exemption. If it is determined that exemption is no longer warranted, then an IRB proposal will need to be submitted and approved before proceeding with data collection.

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ACKNOWLEDGEMENTS

There is great risk in trying to compile a list of people to thank for their support in this endeavor! I'm sure that I'll neglect to mention a particular name so if you are reading this and that's you, forgive me.

First and foremost, I wish to thank my family for their support, especially my wife, Jenifer. There were considerable sacrifices made along the way that had the net effect of putting more of a parental burden on her. For her love and support, I'm grateful. She and our four boys, Cole, Zach, Alec and Nate, have provided the motivation to take on such a journey. I am a blessed man and I love all of you!

Next up are my parents, Bill and Libby Withers. They instilled education and life-long learning into my psyche. They've supported me in every educational endeavor I've ever undertaken. My Dad has been a role model for me my entire life (love of continuing education, science, human health); my Mom has never stopped supporting me and my family. I am grateful that I can be sharing this experience with both of you. A Ph.D. is not the type of doctor I thought I'd become growing up, but I'm thankful and proud of my new title nonetheless and I know you are too. Both of you were a big part of making it happen.

My siblings and extended family (both the Withers and Oldham's) have been supportive throughout. A special thanks to my older brother, Bill, who was especially attentive and supportive having gone through this process himself. Love all around.

A big thank you goes to my employer, Ames Laboratory, and to my boss, Tom Wessels. Without Tom's support, I would have not been able to conduct a research project or take classes. Kate Sordelet and Alison Easter helped collect data; students like Dawn Wolfer and Natalie Hanshaw also helped with data processing. Thanks to all of you.

I am extremely grateful to Dr. David Inyang for allowing me to use his training program as a source of data and allowing me to have access to his staff in order to set up the data collection mechanisms. All of David's folks were awesome, especially Rich McColley and Ruth Book.

All of our friends in the community of Ames deserve a big thank you. There were many times that I was in class and could not drive to an athletic or school event and our friends helped out. Rick Hansen stands out as someone that has helped out the Withers family over the years. Sharing cocktails with friends like the Bappe's and the Kutchen's provided a much needed mental break from "the grind". We love all of you.

Finally, I would like to thank the members of my Committee for their guidance and support and, especially, Dr. Steve Freeman for his encouragement and assistance. Steve, I look forward to working with you in the future as colleagues.